Gale Turi



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Department of Energy
Oak Ridge Operations

Formerly Utilized Sites Remedial Action Program
(FUSRAP)
Contract No. DE-AC05-81OR20722

# PRELIMINARY ENGINEERING EVALUATION OF REMEDIAL ACTION ALTERNATIVES

## ACID/PUEBLO CANYON, LOS ALAMOS, NEW MEXICO

SEPTEMBER 1982

Bechtel Job 14501
Bechtel National, Inc.
Nuclear Fuel Operations

# PRELIMINARY ENGINEERING EVALUATION
# OF REMEDIAL ACTION ALTERNATIVES

## ACID/PUEBLO CANYON SITE
## LOS ALAMOS, NEW MEXICO

## SUMMARY REPORT

SEPTEMBER 1982

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

by

BECHTEL NATIONAL, INC.

OAK RIDGE, TENNESSEE

# FOREWORD

The final engineering summary report that follows reflects an approach agreed upon by DOE-ORO and the Project Management Contractor, Bechtel National, Inc. (BNI). The report is based on information prepared by Ford, Bacon and Davis Utah, Inc. and preliminary engineering performed by BNI. It is not intended that every possible remedial action option be developed in detail in this summary report.

Engineering judgement was used to identify the options that are compared in the cost/benefit (risk) summary. This comparison and back-up information contained in the summary report were prepared to support the selection of a remedial action to be implemented at the Acid/Pueblo Canyon site.

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## INTRODUCTION AND SUMMARY

Under the Formerly Utilized Sites Remedial Action Program (FUSRAP), the U.S. Department of Energy (DOE) has proposed to carry out remedial actions at the Acid/Pueblo site in Los Alamos County, New Mexico. DOE has determined that radionuclides present at the site exceed DOE's proposed clean-up criteria in the areas of the former untreated waste effluent outfall and the former vehicle decontamination facility.

This summary report has been prepared to document the options considered and provide a technical and economical basis for selecting a preferred remedial action to be implemented at the Acid/Pueblo site. In addition to information developed by Bechtel, the Project Management Contractor, it presents information provided to Bechtel by Ford, Bacon and Davis Utah, Inc. (FB&DU), and information from the Environmental Analysis of Acid/Pueblo Canyon, prepared by Los Alamos National Laboratory (LANL)[1].

Appendices A, B, and C include a site history, a detailed site description, and a discussion of remedial action options. Major portions of these appendices were extracted from work performed by Ford, Bacon and Davis Utah, Inc. Appendix D Radiological Data, is extracted verbatim from a LANL report[2].

## CLEAN-UP CRITERIA AND SITE CONTAMINATION

The clean-up criteria that apply at the Acid/Pueblo site are:

| Radionuclide | Soil Limit (pCi/g) |
|---|---|
| Pu-239 | 100 |
| Pu-240 | 100 |
| Pu-241 | 800 |
| Am-241 | 20 |
| Sr-90 | 100 |
| Cs-137 | 80 |

In a survey of the Acid/Pueblo site conducted by LANL[1], contamination was found in the areas of the former untreated waste effluent outfall and the former vehicle decontamination facility. Soil samples taken at specific locations were found to exceed the criteria for remedial action[2].

There are two small areas in Acid Canyon, below the canyon rim in an area of limited access, that approach or exceed the remedial action criteria for Pu-239, i.e., 100 pCi/g in soil. The contaminant is absorbed into the tuff to a depth of a few centimeters along the flowpath of the former untreated waste effluent outfall. Leaving the material in place and applying the worst case assumption of one full year of exposure to an individual would result in a whole body dose commitment equal to 7 percent of the natural background radiation exposure for the Los Alamos area.

Migration of the Pu-239 located below the canyon rim by stream flow could eventually result in a less than 25 percent net increase in the existing plutonium inventory in lower Pueblo Canyon. This increase is within the statistical uncertainty of the estimate of the present inventory in lower Pueblo Canyon. Leaving the plutonium below the rim to migrate and accumulate with the existing inventory in lower Pueblo Canyon should not affect the later selection of remedial action for lower Pueblo Canyon. Therefore, removal of the contaminated tuff below the rim in Acid Canyon is not justifiable considering either low calculated health effects or contamination of lower Pueblo Canyon.

## REMEDIAL ACTION OPTIONS

The three remedial action options being considered for the Acid/Pueblo Canyon site are:

- No action - leaving the property unchanged and incurring no expenses.

- Minimal action - providing for government (federal or county) ownership or control of the contaminated site. The perimeter of the 1-acre site would be fenced to restrict access. The fenced area would include the former untreated waste effluent outfall and the former vehicle decontamination facility area. Surveillance would involve a visual inspection of the site to determine the condition of the fence and to detect any intrusion into the contaminated area.

- Decontamination and disposal - reestablishing the locations of the two general areas requiring decontamination using coordinates from previous LANL surveys. A section of the chain-link fence enclosing the site would be removed to allow access to the areas requiring remedial action. The fence would be replaced when the action is completed, if the county requires it. A barrier would be placed near the canyon rim to prevent loss of excavated material.

  Soil and rock (tuff) would be removed to a depth of from 12 to 18 in. (30 to 46 cm) or as required to meet criteria levels as determined by field measurements taken before and during excavation.

  North of the former untreated waste effluent outfall (Area 1), as shown in Figure 1, an area of about 32 ft by 48 ft (10 m by 15 m) may require decontamination. Area 1 is sloped and may require chipping with jack hammers. South of the outfall, an area (Area 2) of about 32 ft by 48 ft (10 m by 15 m) may require decontamination. At the site of the former vehicle decontamination facility (Area 3), an area of about 48 ft by 80 ft (15 m by 25 m) may require decontamination. Measurements performed during excavation could show that deeper excavation is required along the

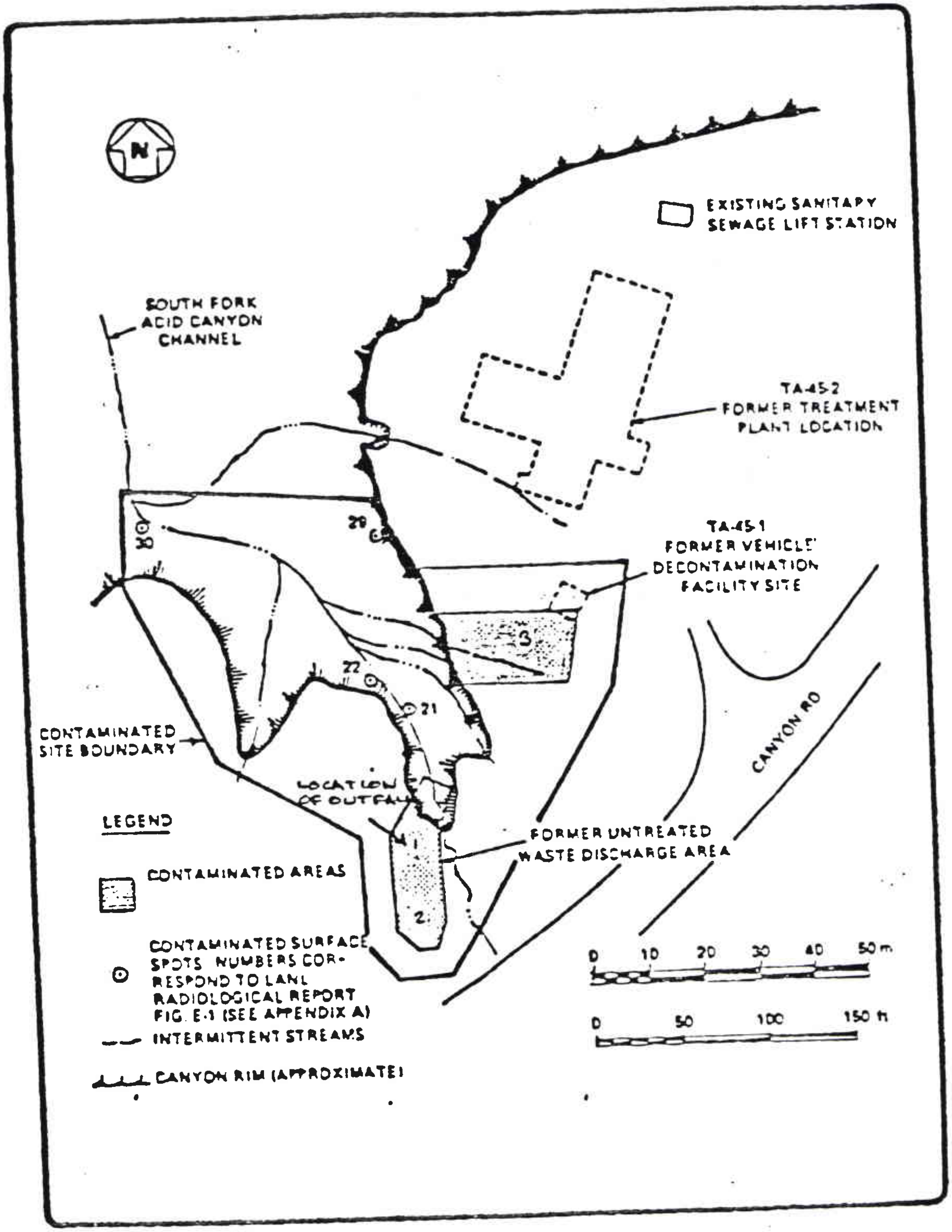


Figure 1. Designated Cleanup Areas of the Acid Canyon Site. Source: Ford, Bacon & Davis Utah Inc. (1981).

immediate flow path below the former untreated waste effluent outfall due to deeper penetration of the effluent into the tuff rock. The total volume of rock and soil to be removed is preliminarily estimated to be about 300 $yd^3$ (230 $m^3$). As stated previously, field measurements taken before and during excavation could significantly reduce the volume of material requiring excavation. In particular, field measurements will determine whether it is cost effective to clean hot spots located in Area 3 under the ALARA (As Low As Reasonably Achievable) principle.

Health physics coverage would be provided during the course of the remedial action. Dust and contaminated water control would be provided as required. The excavated material would be loaded on trucks and transported to TA-54, the radioactive solid waste disposal facility at LANL. The contaminated soil would be handled according to standard disposal procedures. The excavated and disrupted areas of the site would be allowed to stabilize and revegetate naturally.

## COST/BENEFIT SUMMARY

Table 1 is a cost/benefit summary for the remedial action options that were considered for the Acid/Pueblo site. The costs shown for the options are preliminary Bechtel estimates.

Decontamination of the site and disposal of the waste is a permanent solution to the contamination problem. The site would be available for unrestricted use, and no surveillance or monitoring would be required. Decontamination and disposal costs could be reduced from $95,500 to $42,000 if the former vehicle decontamination facility does not require remedial action.

Minimal action, which would involve fencing of about 1 acre, would result in essentially no environmental impacts. Long-lived radionuclides could migrate, however, and the fence would have to be repaired and replaced several times. Minimal action would require annual monitoring and quarterly surveillance.

The no-action option leaves the property unchanged, but the potential for exposure to contamination in concentrations above clean-up criteria and spread of contamination still exists.

## ENVIRONMENTAL CONSIDERATIONS

An environmental analysis[1] performed for the Acid/Pueblo site determined that essentially no environmental impacts are associated with either the no-action or minimal action alternatives. The impacts associated with the clean-up alternative are insignificant.

TABLE 1

COST/BENEFIT SUMMARY

ACID/PUEBLO SITE

| OPTION | DESCRIPTION | COST(1) | DISCUSSION/BENEFITS (RISK) |
|---|---|---|---|
| No action | Property unchanged | None | Contamination on site continues the potential for radiation exposure and spread of contamination. There are no new environmental impacts associated with this option. |
| Minimal Action | Fence an area of about 1 acre encompassing the untreated waste effluent outfall and the vehicle decontamination facility site. | \$46,000(2) | The discussion for no action applies to this option including essentially no environmental impacts. Fencing minimizes the potential for radiation exposure; however, because of the long-lived radio-isotopes present, repair and replacement of the fence will be required in the future. |
| Decontamination and Disposal | Decontamination of readily accessible areas of surface contamination exceeding the criteria at the site of the former vehicle decontamination facility and around the former untreated waste effluent outfall. The maximum quantity of material to be excavated and disposed of is estimated to be 300 $yd^3$. The smaller, more inaccessible sites of above-criteria surface contamination below the canyon rim would not be affected by this alternative. | \$95,500(3) | As a result of this option, a permanent solution is obtained. The site will be available for unrestricted use and no surveillance or monitoring will be required. Radioactivity is reduced to criteria levels or less.<br><br>Implementing this option has the greatest potential for short-term adverse environmental impacts. |

(1) Preliminary cost estimate by Bechtel National, Inc.

(2) Minimal action requires an additional cost for annual monitoring and quarterly surveillance of \$5000/yr. The cost to replace the fence (due to the presence of long-lived radioisotopes) would be equivalent to original expenditures in 1982 dollars. Therefore, total costs for this option would exceed costs for decontamination within 10 years and would ultimately be significantly higher.

(3) Cost would vary significantly for decontamination and disposal if field measurements, before and during excavation, show significant reductions in the amount of material requiring excavation and disposal. If it is determined that the former vehicle decontamination area does not require remedial action, decontamination and disposal cost could be reduced to \$42,000.

## REFERENCES


(1) "Environmental Analysis of the Acid/Pueblo Canyon Site"; Los Alamos National Laboratory; Los Alamos, NM; 1982.

(2) "Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, New Mexico"; prepared for the U.S. Department of Energy under Contract W-7405-ENG-36; Report No. DOE/EV-005-30; Los Alamos Scientific Laboratory, Los Alamos, NM; 1981.

# APPENDIX A

# SITE HISTORY

# SITE HISTORY

The United States Government has instituted a program entitled "Formerly Utilized MED/AEC Sites Remedial Action Program", or FUSRAP. This remedial action program for the Manhattan Engineer District (MED)/Atomic Energy Commission (AEC) sites was initiated in 1974 by the AEC, was continued under the Energy Research and Development Administration (ERDA), and is presently being managed by the Department of Energy (DOE). The objectives of this DOE program include determining the radiological conditions of the former MED/AEC sites, proposing remedial action options that could be undertaken where corrective actions are necessary, analyzing the environmental impacts, and estimating the costs associated with the remedial action.

A portion of Acid/Pueblo Canyon, located in Los Alamos County in north-central New Mexico, has been designated as a former MED/AEC site because between 1943 and 1964 untreated and treated liquid wastes were discharged into the two canyons. The wastes were generated by nuclear weapons research activities at the Los Alamos National Laboratory (LANL). Initial research was performed under the auspices of the MED and later for the AEC. A waste treatment plant located at the site was decontaminated and decommissioned in 1967. However, a portion of the site still contains contamination that is above proposed criteria.

Radioactive liquid wastes resulted from work started in 1943 as part of the MED project to develop a nuclear fission weapon. Nuclear weapons development was carried on after 1947 under the auspices of the AEC. Untreated liquid wastes were discharged into Acid Canyon starting in late 1943 or early 1944 and continued to be discharged through April 1951. The effluents contained radioactive isotopes from the research and processing operations. It is known that the discharges included isotopes of strontium, cesium, uranium, plutonium, americium, and tritium. A waste treatment plant (TA-45) was constructed on the rim of Acid Canyon and became operational in June of 1951. From startup until 1953 the plant treated liquid wastes from the main technical area (TA-1) only. Starting in June 1953, additional liquid wastes were received from a new laboratory complex (TA-3) south of Los Alamos Canyon. A high percentage of the TA-3 waste was released untreated into Acid Canyon from 1953 to 1958. In September of 1953, liquid wastes from the health research laboratory (TA-43) were discharged to the waste treatment plant. In 1958, liquid wastes from a new radiochemistry facility (TA-48) were discharged to the line from TA-3. In July 1963, the wastes from TA-3 and TA-48 were redirected to a new central waste treatment plant (TA-50) located south of Los Alamos Canyon within the present LANL site. The liquid wastes from TA-43 were redirected to the sanitary system because at this time only small quantities of very low-level wastes were generated. Only liquid wastes from TA-1 were processed at TA-45 from July 1963 to the cessation of operations in May of 1964[1].

In the past, the Acid/Pueblo Canyon site was referred to as Technical Area 45 (TA-45). As shown in Figure A-1, the principal structures comprising TA-45 included a vehicle decontamination facility (TA-45-1) and the waste treatment plant (TA-45-2). Figure A-2 shows the waste lines feeding the treatment plant.

Decommissioning and decontamination of the TA-45 waste treatment plant area began in October 1966. All contaminated building materials were disposed of at the LANL radioactive waste burial site. Contaminated sewer pipe and soil from the vehicle decontamination facility were also disposed of at LANL. Simultaneously, portions of Acid Canyon were decontaminated. Contaminated tuff and rock were removed from the cliff face. Some contaminated rock, soil, and sediment also were removed from the canyon floor. By July 1967 the areas around the former TA-45 waste treatment plant site and in Acid Canyon were considered sufficiently free of contamination to allow unrestricted access(1).

After decommissioning, the land was transferred from the U.S. Government to Los Alamos County by quit-claim deed on July 1, 1967. It was recognized at the time of decommissioning that some radioactive materials probably remained in the canyon. Consequently, several follow-up radiological surveys were conducted over the years(1).

Monitoring programs by LANL personnel to study the untreated effluents that were discharged into Acid and Pueblo Canyons as well as other canyons were conducted in 1945, 1946, and 1947. The results of these surveys showed that radionuclide concentrations decreased downgradient as the untreated wastes were diluted with sanitary effluent and storm runoff, and by adsorption or ion exchange of radionuclides with sediments in the stream channel(2).

From 1949 to 1971, the Water Resource Division of the U.S. Geological Survey (USGS) studied the effects of the release of industrial effluents on the water quality and geohydrology of the area. The data collected and analyzed were summarized in a series of USGS reports covering the period 1949 through 1967. Environmental data subsequently gathered by LANL were summarized in a series of reports from 1970 through 1974(1). The results of the studies showed that most of the residual activity is attached to bank soils or more stable inactive channel sediments.

In 1972, the LANL performed a radiation survey of the canyon bottom in the midreach of Pueblo Canyon to determine the impact of LANL activity. This was part of an overall survey conducted north of Pueblo Canyon to which Acid Canyon is a tributary. Tritium in vegetation was slightly higher than regional background, but other nuclides in soil and vegetation were similar to regional background concentrations.

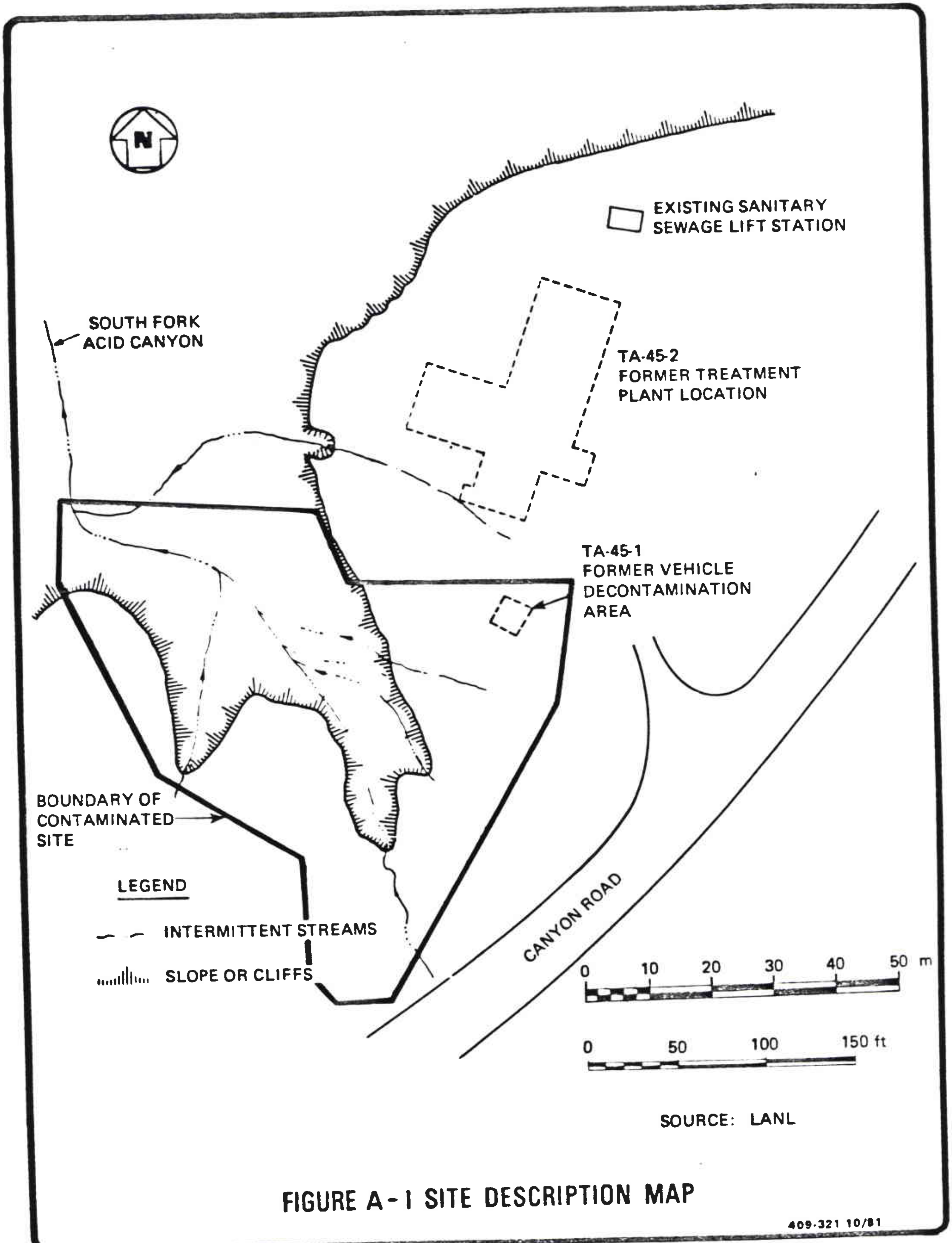


FIGURE A-1 SITE DESCRIPTION MAP

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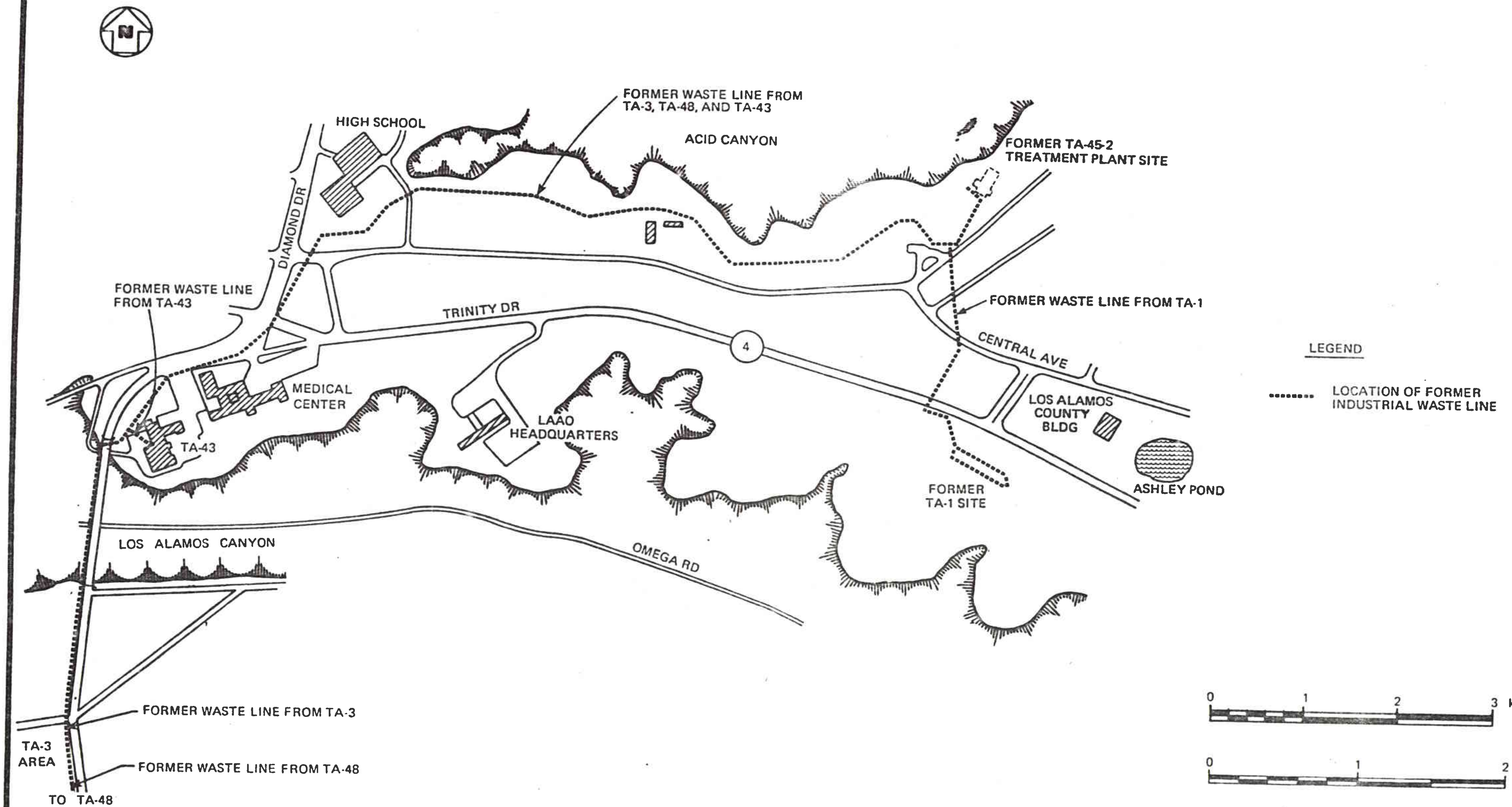


FIGURE A-2 INDUSTRIAL WASTE LINES FROM TECHNICAL AREA FACILITIES TO FORMER TA-45 TREATMENT PLANT

SOURCE: LANL

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In 1976, ERDA identified the Acid/Pueblo Canyon site as an MED/AEC site. Consequently, LANL personnel began a resurvey for possible residual contamination. The radiological survey was completed in 1977, and the final report[1] on the survey results was issued in May 1981. The results of this survey indicated that the Acid/Pueblo Canyon site should be considered for remedial action[2].

Current uses of Acid/Pueblo Canyon include picnicking, trail riding, hiking, firearms practice, woodcutting, and pinon nut gathering. Projected future use includes possible residential development[1].

## APPENDIX A REFERENCES

1. "Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, NM"; Final Report; for U.S. Department of Energy, Assistant Secretary for Environment, Division of Environmental Control Technology, Washington, D.C.; by Los Alamos Scientific Laboratory, Los Alamos, New Mexico; under Contract W-7405-ENG-36; Report No. DOE/EV-0005/30; 1981.

2. "A Background Report for the Formerly Utilized MED/AEC Sites, Remedial Action Program"; Draft Report; by Environmental Controls and Analysis Directorate, Eastern Technical Division, The Aerospace Corporation; for the Division of Environmental Control Technology, Assistant Secretary for Environment, U. S. Department of Energy; under Contract No. EX-76C-03-110 (PA-10); Dec 1978.

APPENDIX B

SITE DESCRIPTION

# SITE DESCRIPTION

The site is located in Acid/Pueblo Canyon in north-central New Mexico, in Los Alamos County, adjacent to the town of Los Alamos. Albuquerque is about 62 mi (100 km) to the south-southwest by air, and Santa Fe is about 25 mi (40 km) to the southeast by air. Figure B-1 shows the site location, and Figure B-2 is a site vicinity map. Access to the site from the townsite of Los Alamos is by Canyon Road, which runs just to the south of the former TA-45 waste treatment plant. The boundary of the site has been designated to encompass approximately 1 acre.

As shown in the aerial view of the Acid/Pueblo Canyon site, Figure B-3, the contaminated site is located adjacent to Acid Canyon which is tributary to Pueblo Canyon. The contaminated site area is bounded by a residential subdivision to the north and the townsite of Los Alamos to the south. Figure B-4 shows the physiographic setting of the site and indicates the Los Alamos County boundary.

## PHYSICAL CONDITIONS

The area in the vicinity of the site has a semi-arid mountain climate characterized by normally fair weather. The average temperature in July is about 73°F (23°C) and in January about 21°F (-6°C)[1]. Thundershowers in late summer provide most of the total annual precipitation; winter snows provide the remainder. Water flow in canyon streams is intermittent, with most of the runoff occurring in July and August during and after heavy thunderstorms. The runoff period is generally short, e.g., several hours. The average annual precipitation increases from about 9 in. (23 cm) along the Rio Grande River to about 18 in. (46 cm) on the mesa plateaus, to about 30 in. (76 cm) along the crest of the mountains in the immediate vicinity of Los Alamos. Overstory vegetation ranges from juniper and grasslands at lower elevations to fir, spruce, pinon pine, and subalpine grasslands at the higher elevations along the crest of the mountains[1].

Pueblo Canyon heads on the Pajarito Plateau and is tributary to the lower reach of Los Alamos Canyon, which in turn drains into the Rio Grande River. Acid Canyon is a headwaters tributary of Pueblo Canyon near the Los Alamos townsite.

The general geology of the Los Alamos area centers around the Pajarito Plateau. The eastern edge of the plateau has been eroded from Bandelier Tuff. The Bandelier Tuff is more than 984 ft (300 m) thick in the western part of the plateau and about 262 ft (80 m) thick near the Rio Grande River[2].

Although the streams in Acid and Pueblo Canyons flow only intermittently, they have cut deep into the rock units forming and underlying the Pajarito Plateau. Acid Canyon and the headwaters area of Pueblo Canyon are underlain by the Tshirege Member of the Bandelier Tuff. The Tshirege Member consists primarily of nonporous welded rhyolite tuff[2].

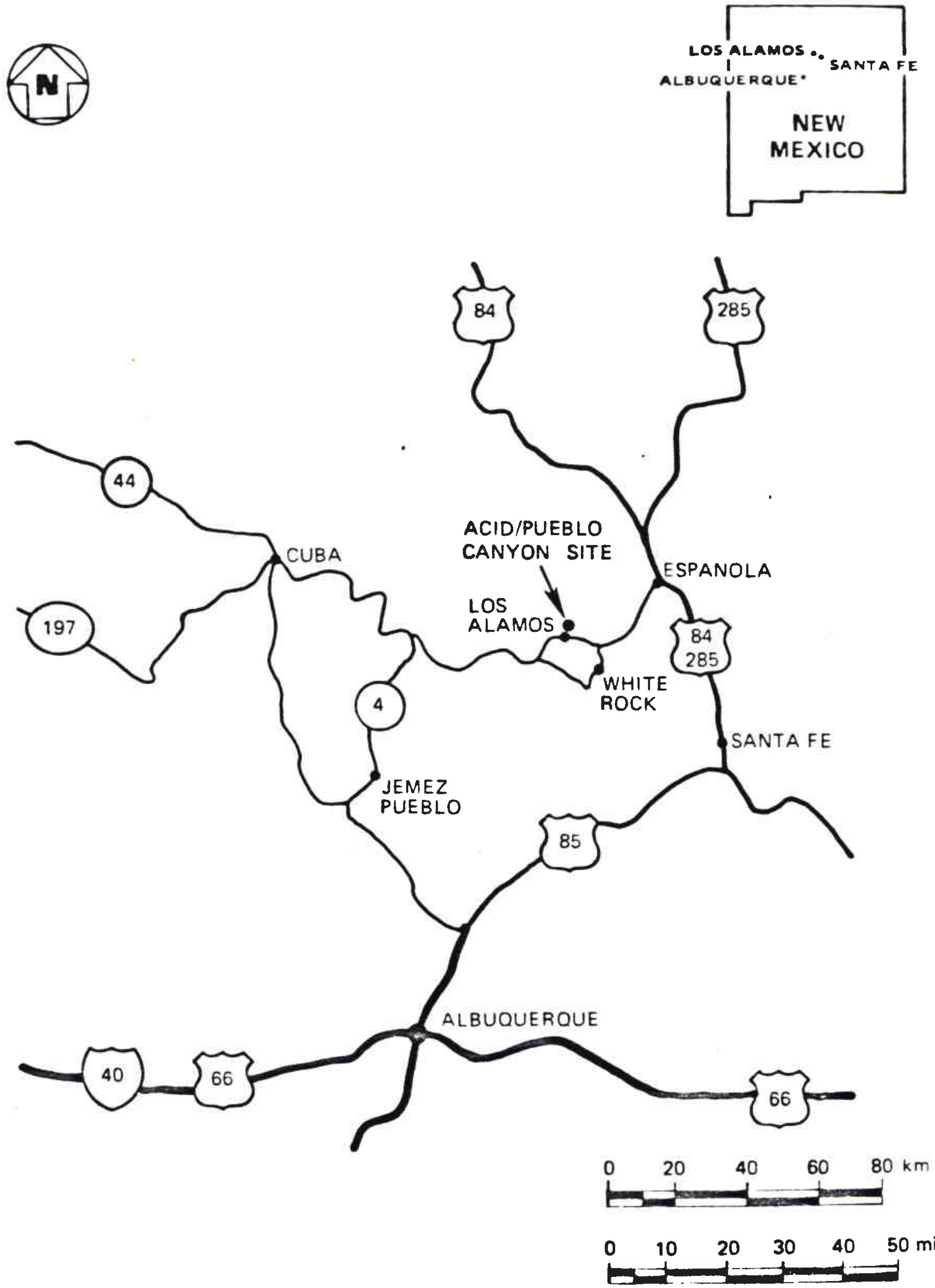


FIGURE B-1 SITE LOCATION MAP

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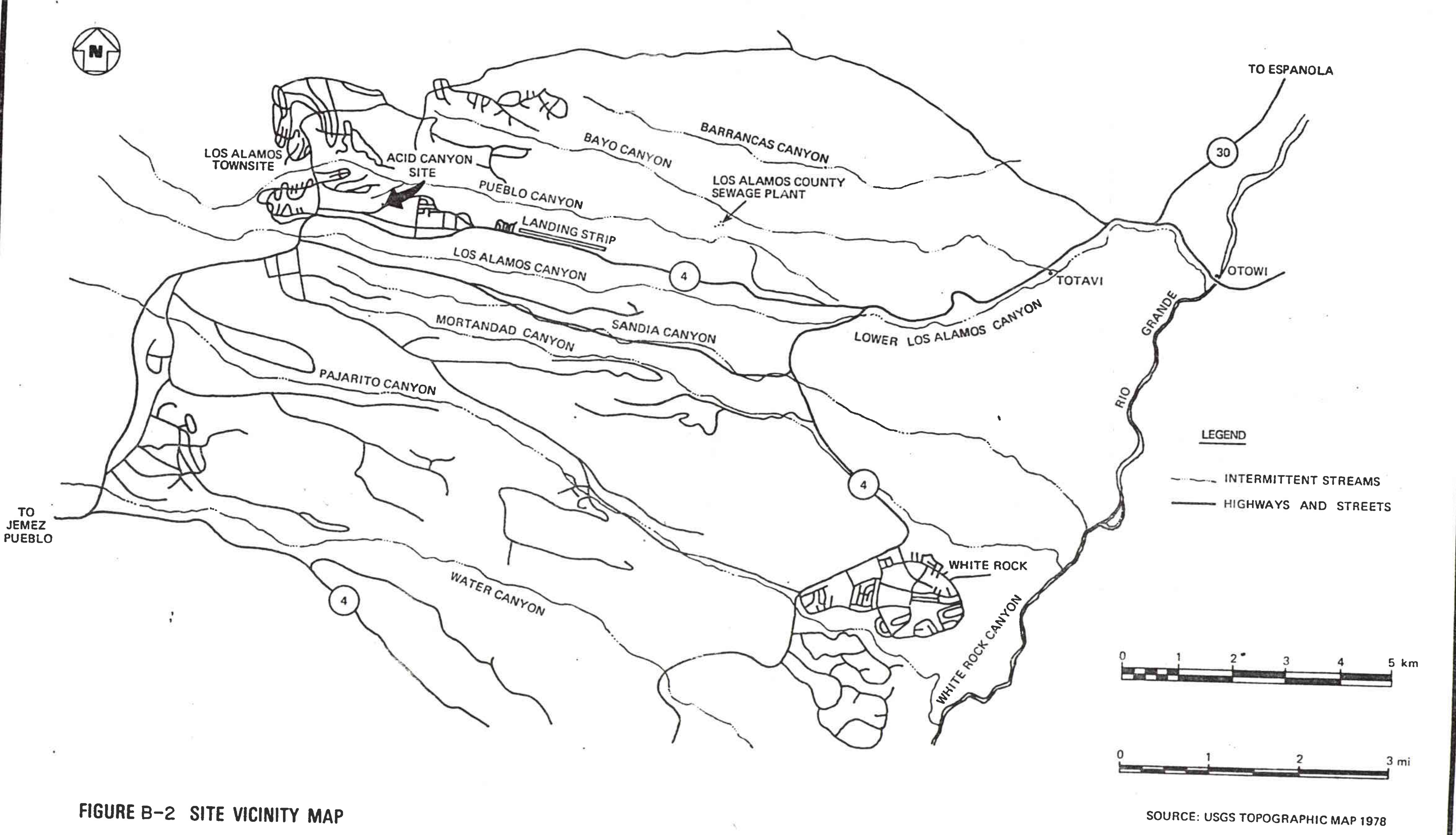


FIGURE B-2 SITE VICINITY MAP

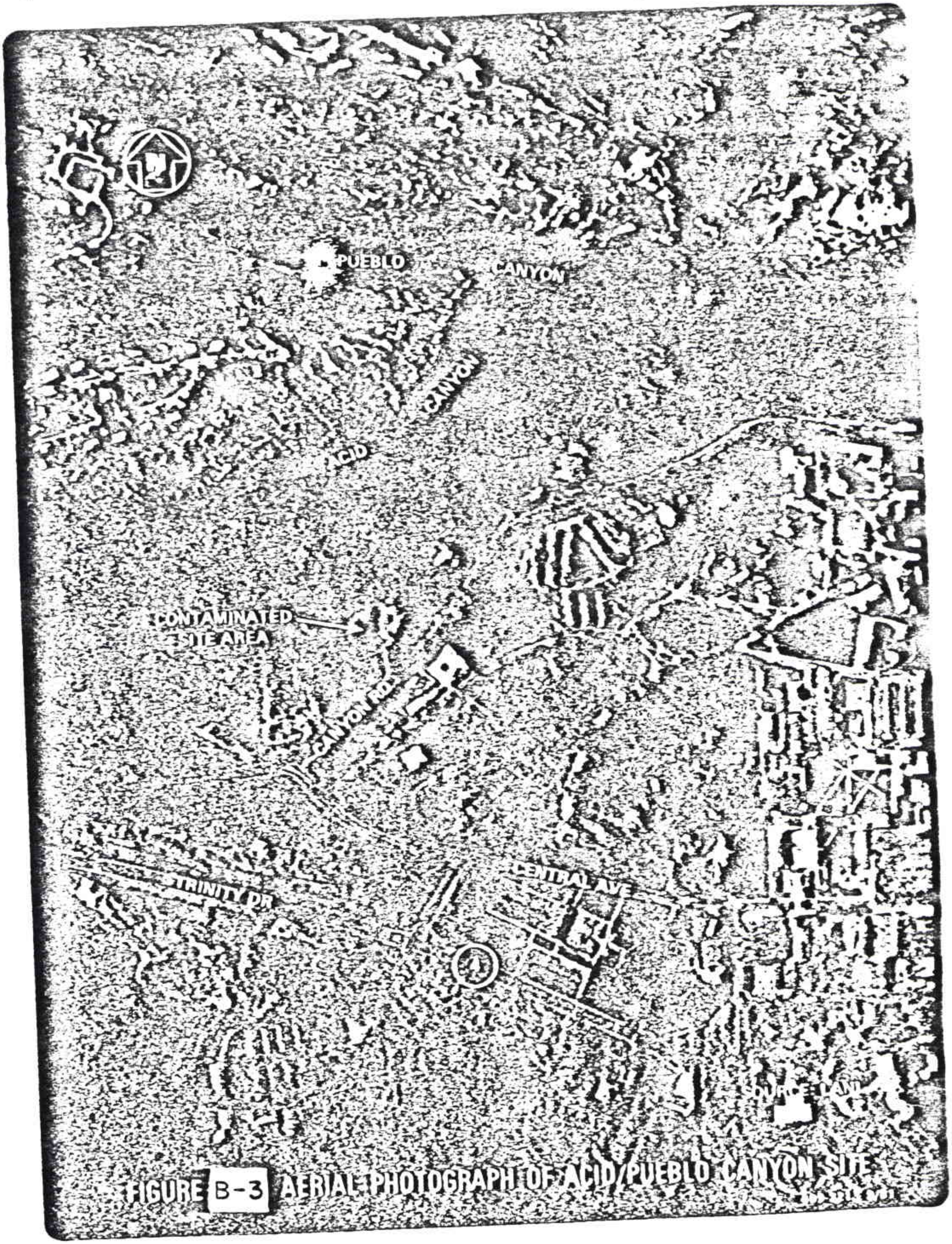

FIGURE B-3 AERIAL PHOTOGRAPH OF ACID/PUEBLO CANYON SITE

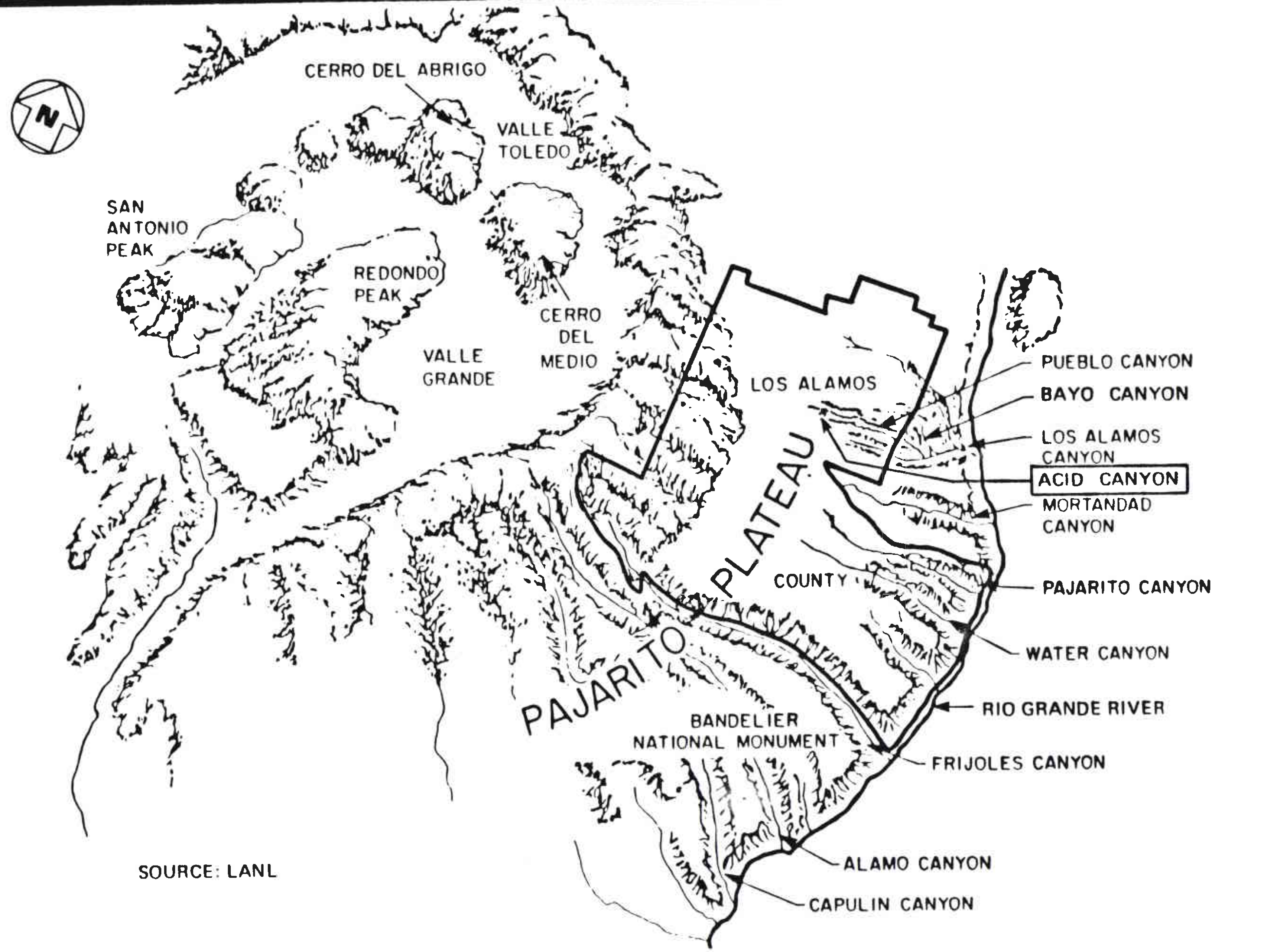


FIGURE B-4 PHYSIOGRAPHIC SETTING OF ACID CANYON

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From just below its confluence with Acid Canyon to a point about 3 mi (4.8 km) above its confluence with lower Los Alamos Canyon, Pueblo Canyon is underlain mainly by the Otowi Member of the Bandelier Tuff. The Otowi Member is a massive aggregate of poorly sorted rhyolitic pumice fragments and some fine pumice glass. This member contains only a limited amount of perched ground water. The remainder of Pueblo Canyon down to the confluence with lower Los Alamos Canyon is underlain by Puye Conglomerate. This conglomerate consists of interbedded silt, sand, and gravel derived from contemporaneous erosion and volcanism(2).

Intermittent natural runoff and effluent from a waste water treatment plant (see Figure B-2) recharge a small body of perched ground water in the midreach of Pueblo Canyon(1). However, available data(1) suggest there is no hydrologic connection between the perched aquifer and the deep aquifer furnishing potable water in the Los Alamos area. The deep aquifer is located approximately 790 ft (240 m) below the surface(2).

The Acid/Pueblo site is located in a Zone 2 seismic area, where moderate damage from earthquake can be expected to occur. The earthquake recorded nearest to the site occurred in Santa Fe County to the southeast on May 18, 1918. The quake was graded at Intensity VII to VIII (Modified Mercalli). The most recently recorded event occurred on January 22, 1966 at Dulce, about 70 mi (113 km) northwest of the site. The magnitude of this event was measured at 5.5 on the more recently developed Richter scale(3).

## RADIOLOGICAL CONDITIONS

LANL performed a radiological survey of the Acid/Pueblo Canyon test site for DOE in 1976-1977(1). Data on surface and subsurface soils, air concentrations, and gamma surveys were obtained. The information presented in the following paragraphs is a summary of the findings of the radiological surveys performed by LANL and supplemented by FB&DU in 1980. The LANL survey data are included as Appendix D of this report.

No waste water treatment facility existed between 1943 and 1951. The untreated effluent discharged to Acid Canyon during this period contained about 150 mCi of plutonium (a LANL estimate). The TA-45 waste treatment plant was put into operation in 1951. From 1951 to 1964, the plutonium release was reduced to 26.9 mCi. Other radionuclides released in the untreated effluent included Sr-90, Cs-137, U-238, Pu-241, Am-241, and H-3 (tritium).

Surface and subsurface contaminated areas near the former TA-45 waste treatment plant area are indicated in Figure E-1 of the LANL report(1) (included in Appendix D of this report). The highest concentration of contamination was found in the top 10 in. (25 cm) of soil near the site of the former decontamination facility. Lower concentrations were found in Acid Canyon, middle and lower Pueblo Canyon, and were detectable in lower Los Alamos Canyon. At the top of the mesa, a small area with high surface concentrations of Pu-239 was found near the location of the former industrial waste discharge line. The highest concentration detected was 163,000 pCi/g. In the same area, Sr-90 concentrations ranged from 0.5 to 230 pCi/g, Cs-137 from 0.1 to 180 pCi/g, and U-238 from 0.3 to 200 pCi/g.

In Acid Canyon, the LANL measurements showed average concentrations of Pu-239 of 31 pCi/g in the stream bed and 110 pCi/g in the banks, along with up to a maximum of 630 pCi/g of other radionuclides. The average Sr-90 was 1.0 pCi/g, Cs-137 was 1.9 pCi/g, and U-238 was 0.43 pCi/g. Figure B-5 shows the sample locations in Acid Canyon.

In middle Pueblo Canyon, the only significant contaminant detected by LANL was Pu-239, where a maximum concentration of 88 pCi/g was measured. However, this concentration still was below 100 pCi/g[4]. The Pu-239 was at detectable levels at all sampling points in Pueblo Canyon and in lower Los Alamos Canyon to its confluence with the Rio Grande River. Other radionuclides were within normal background ranges.

Personnel from FB&DU gathered soil samples to supplement (but not duplicate) the LANL soil data and to verify the expected background radionuclide concentrations in the area. For instance, K-40 (a beta emitter) is found naturally in soils around Los Alamos and contributes to gross beta levels. In addition, natural concentrations of Ra-226, Th-232, and natural uranium affect gross alpha levels. The low concentrations of these radionuclides in all FB&DU soil samples demonstrate that the elevated gross alpha found at some locations by LANL is due to plutonium contamination.

The FB&DU subsurface soil samples were from holes drilled at the confluence of Pueblo Canyon with Los Alamos Canyon and at a point below Totavi. Surface soil samples were taken in Pueblo Canyon, in Acid Canyon, and at the face of the cliff in the south fork of Acid Canyon near the former TA-45 treatment plant. These sample locations are shown in Figures B-5 and B-6. Results of the analyses are shown in Table B-1.

The LANL soil samples were tested for gross alpha and gross beta. A representative number of these samples also were tested for specific nuclides, including Sr-90 (a beta emitter). Soil samples collected by FB&DU in 1980 contained concentrations of K-40 (also a beta emitter) ranging from 9 to 59 pCi/g. However, in every LANL sample analyzed for Sr-90, if the gross beta reading exceeded 100 pCi/g, the Sr-90 result was also greater than 100 pCi/g. The gross beta reading thus appears to be a valid, although conservative, indicator for soil concentrations of Sr-90.

The combined effect of alpha and beta contamination also was considered. When two or more radionuclides are present in a soil sample, the maximum permissible concentration (MPC) of each will be limited to the extent that the sum of the ratios of the nuclide concentrations to the MPC's of the nuclides must not exceed unity. Thus, if $C_1$, $C_2$, $C_3$, ...Cn represent the concentrations of

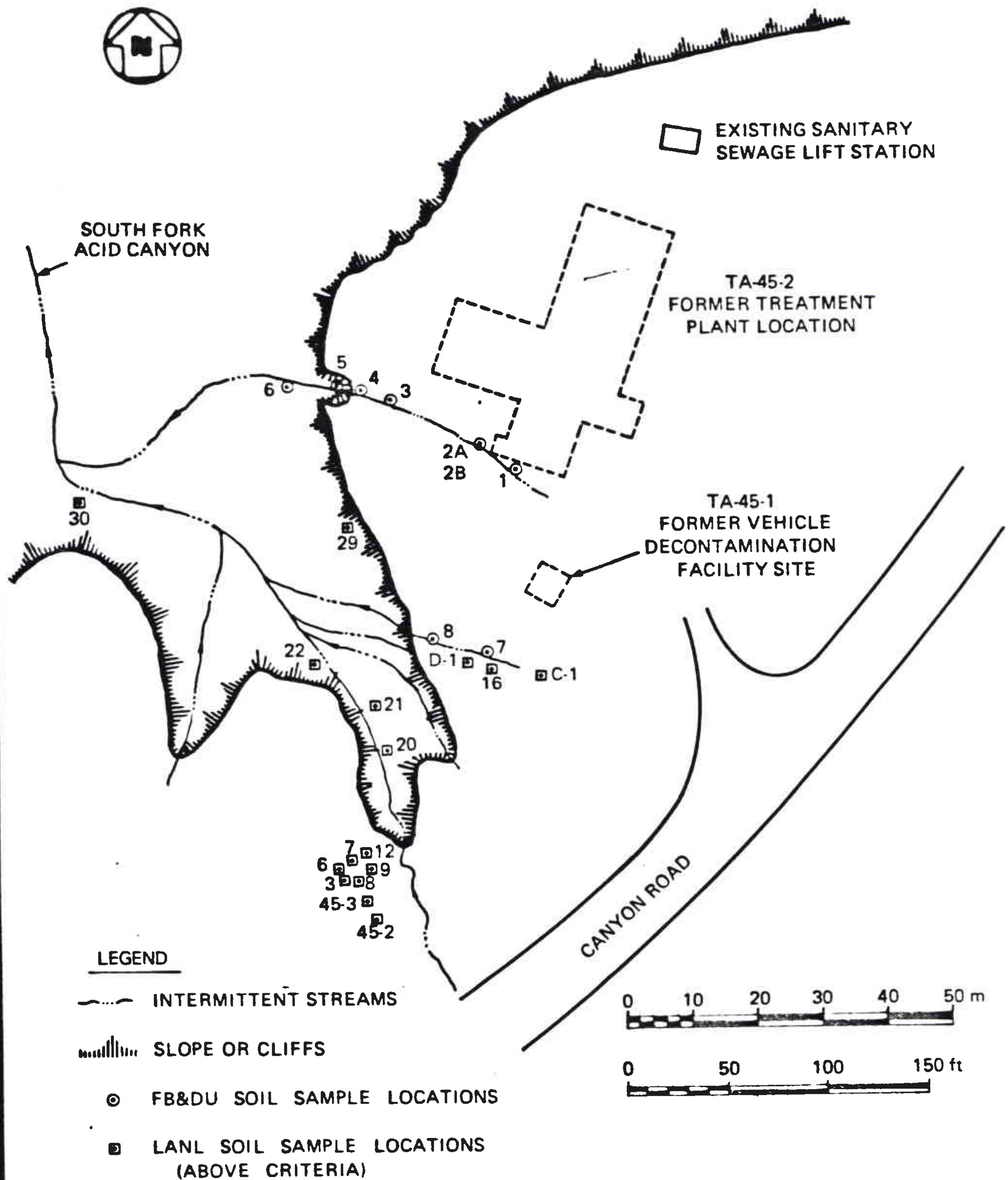


FIGURE B-5 SOIL SAMPLE LOCATIONS IN ACID CANYON

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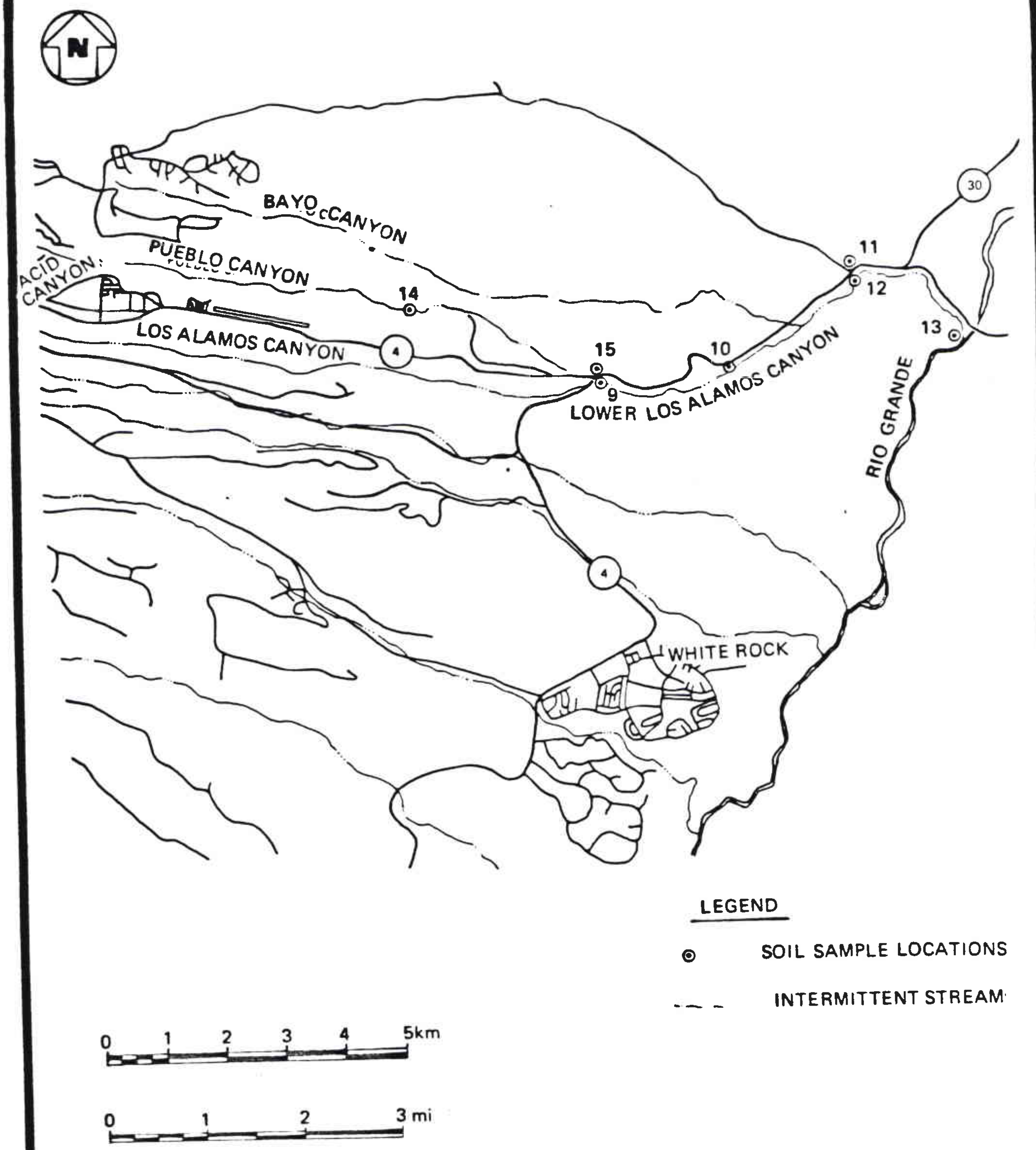


FIGURE B-6 SOIL SAMPLE LOCATIONS IN PUEBLO AND LOWER LOS ALAMOS CANYONS

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TABLE B-1

FB&DU SOIL SAMPLE DATA FROM ACID/PUEBLO CANYONS[a]

| Sample No.(b) | Depth (ft.) | Cs-137 (pCi/g) | K-40 (pCi/g) | Ra-226 (pCi/g) | Th-232 (pCi/g) | U-238 (pCi/g) | Pu-239 (pCi/g) |
|---|---|---|---|---|---|---|---|
| 1 | | 0.24 | 42.9 | 2.3 | 0.16 | 0.43 | 0.01 |
| 2A | 0-1 | 0.05 | 16.2 | 1.3 | 0.05 | 0.01 | 0.01 |
| 2B | 1-2 | 0.01 | 24.5 | 2.6 | 0.06 | 0.47 | 0.08 |
| 3 | Surface | 0.01 | 59.1 | 2.3 | 0.05 | 0.30 | 0.07 |
| 4 | Surface | 0.01 | 33.8 | 3.4 | 0.05 | 0.20 | 0.05 |
| 5 | Surface | 0.62 | 26.6 | 0.94 | 0.05 | 0.73 | 0.05 |
| 6 | Surface | 0.18 | 22.2 | 1.7 | 0.05 | 0.27 | 0.07 |
| 7 | Surface | 0.01 | 15.4 | 0.97 | 0.05 | 0.07 | 0.01 |
| 8 | Surface | 0.10 | 16.6 | 1.1 | 0.05 | 1.70 | 0.09 |
| 9 | Surface | 4.89 | 23.1 | 0.05 | 0.06 | 0.13 | 0.01 |
| 10 | Surface | 0.95 | 21.6 | 1.7 | 0.05 | 0.01 | 0.01 |
| 11 | Surface | 0.01 | 19.9 | 1.3 | 0.05 | 0.07 | 0.01 |
| 12A | 0-1 | 0.60 | 23.1 | 1.6 | 0.05 | 0.10 | 0.01 |
| 12B | 1-2 | 0.61 | 20.8 | 0.62 | 0.05 | 0.10 | 0.01 |
| 13 | 0-1 | 0.44 | 23.9 | 1.1 | 0.05 | 0.07 | 0.01 |
| 14A | 0-3 | 0.01 | 9.06 | 0.79 | 0.05 | 2.80 | 0.01 |
| 14B | 3-6 | 0.07 | 16.3 | 0.98 | 0.05 | 0.07 | 0.01 |
| 14C | 6-9 | 0.01 | 17.3 | 0.48 | 0.05 | 0.30 | 0.01 |
| 14D | 9-12 | 0.01 | 18.7 | 1.9 | 0.05 | 1.17 | 0.01 |
| 15A | 0-3 | 0.12 | 34.7 | 1.9 | 0.05 | 1.37 | 0.05 |
| 15B | 3-6 | 0.05 | 25.5 | 0.63 | 0.05 | 0.01 | 0.09 |
| 15C | 6-9 | 0.01 | 23.8 | 2.1 | 0.05 | 0.73 | 0.01 |
| 15D | 9-12 | 0.01 | 21.0 | 1.9 | 0.05 | 0.27 | 0.01 |

(a) Sample analysis performed by Controls for Environmental Pollution Inc. under subcontract with Ford Chemical Laboratory.

(b) Sample locations are shown in Figures B-5 and B-6.

each nuclide present in a particular soil sample, and if M1, M2, M3,...Mn represent the MPC's of these nuclides, then the maximum permissible concentrations of the combined nuclides in the sample are limited by the equation:

$$\frac{C_1}{M_1} + \frac{C_2}{M_2} + \cdot \cdot \cdot \frac{C_n}{M_n} \leq 1.00$$

In all sample locations where cleanup is required, at least one nuclide exceeds its criterion.

## External Gamma Radiation

The variations in external gamma radiation measured by LANL were verified by FB&DU measurements (9 to 17 μR/hr). Measurements were within the range of natural background variations, except at the TA-45 treatment plant area. In the vehicle decontamination facility area, the exposure rate from contamination was estimated to be up to 40 μR/hr above background. Gamma levels in the open drainage from the untreated waste outfall were measured up to 50 μR/hr above normal background.

## Radon and Radon Daughter Concentrations

Personnel from FB&DU collected and measured some radon gas samples in the site area and at various locations in Pueblo and lower Los Alamos Canyons as shown in Figure B-7. Analyses of the samples confirmed that radon flux concentrations were within the expected background range of 1 to 3 $pCi/m^2$-s. Table B-2 notes the measurements and results.

## Water Samples

FB&DU obtained water samples from Acid and Pueblo Canyons just above their confluence and from Pueblo Canyon just below this confluence. Samples were taken from the Rio Grande River just above and below its confluence with lower Pueblo Canyon. Water sample locations were limited due to the intermittent flow in Pueblo Canyon. The five water sample locations are shown in Figure B-8. Results of analyses of these samples are shown in Table B-3. Results show that the nuclides considered are below maximum permissible concentrations[(4)].

## Contaminated Areas

Radioactive contamination above guideline criteria was detectable by FB&DU in its 1980 survey only in the main branch of Acid Canyon and on the top of the mesa between Canyon Road and the south rim of the south fork of Acid Canyon. Consequently, based on interpretation of the data obtained by LANL and FB&DU, the only areas requiring remedial action are those shown in Figure B-9.

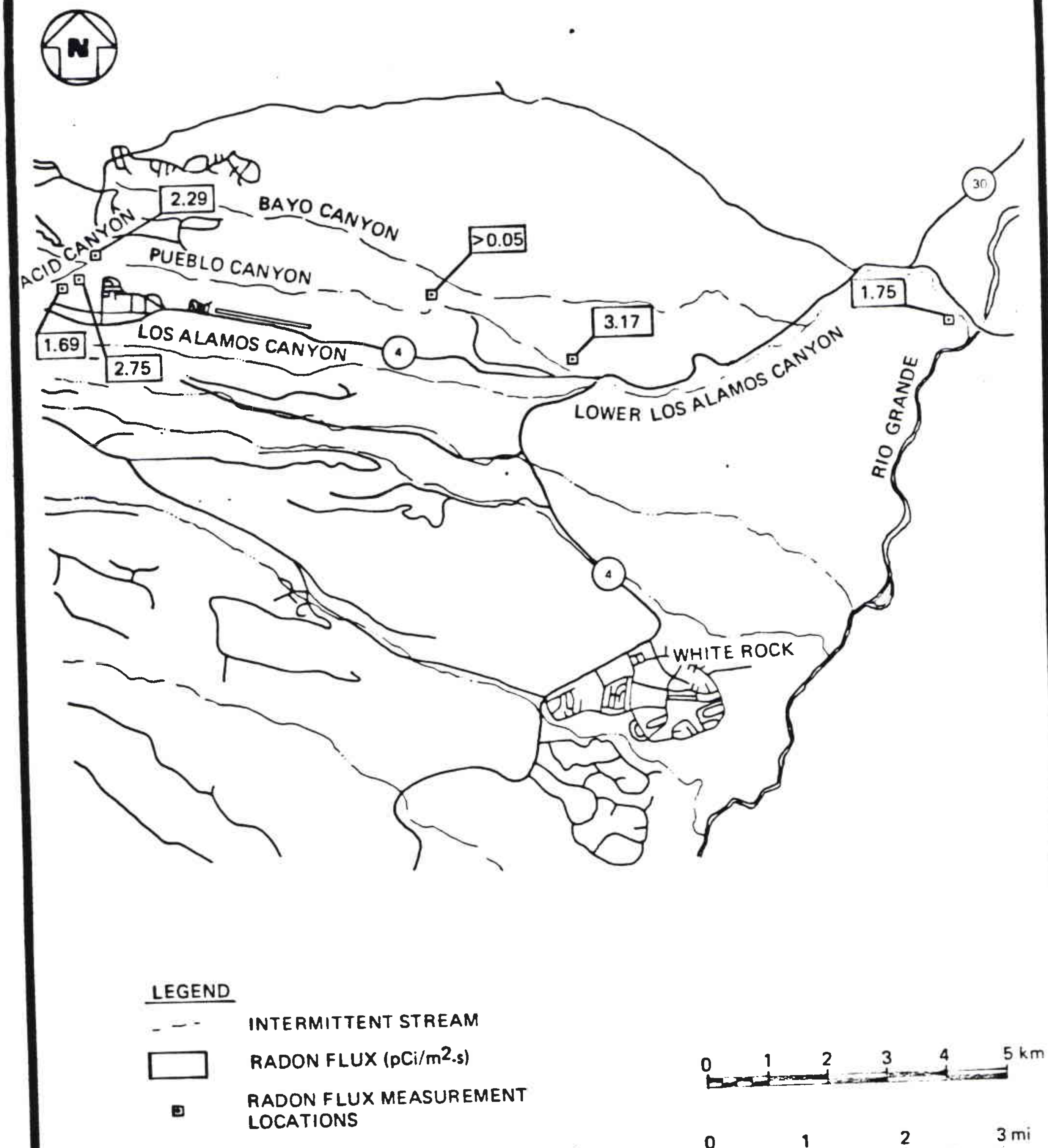


FIGURE B-7 RADON FLUX CANISTER LOCATIONS IN ACID, PUEBLO, AND LOWER LOS ALAMOS CANYONS

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**TABLE B-2**

RADON FLUX MEASUREMENTS - ACID/PUEBLO CANYONS

| Location | Flux (pCi/$m^2$-s) |
|---|---|
| Acid treatment plant site | 2.75 |
| Base of cliff in Acid Canyon | 1.69 |
| Pueblo Canyon - stream bed below confluence with Acid Canyon | 2.29 |
| Pueblo Canyon - Drill hole 14 | 0.05 |
| Pueblo Canyon - above confluence with Los Alamos Canyon | 3.17 |
| Alamos Canyon - above confluence with io Grande River | 1.75 |

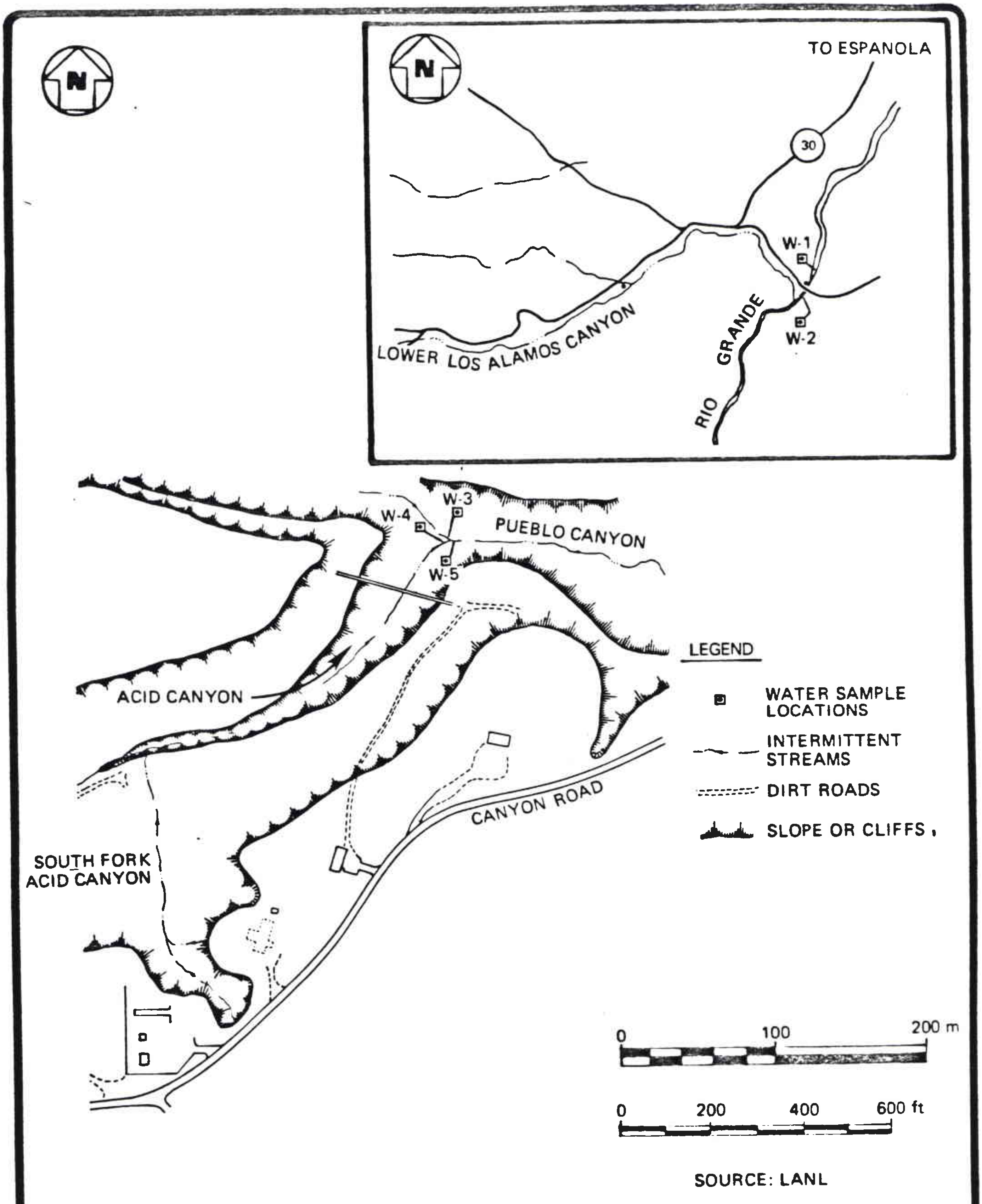


FIGURE B-8 WATER SAMPLE LOCATIONS

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TABLE B-3

FB&DU SURFACE WATER SAMPLE DATA FROM ACID/PUEBLO CANYONS
(in pCi/l)

| Sample No. | Cs-137 | Sr-90 | Ra-226 | U-238 | Gross α | Gross β |
|---|---|---|---|---|---|---|
| 1 | 8 | 0.05 | 0.60 | 0.02 | 2.0 | 3.0 |
| 2 | 8 | 0.05 | 0.60 | 0.08 | 10.0 | 3.0 |
| 3 | 8 | - | 0.60 | 0.06 | 2.0 | 4.0 |
| 4 | 8 | - | 0.60 | 0.04 | 2.0 | 33.0 |
| 5 | 8 | - | 0.60 | 0.04 | 7.0 | 9.0 |

*Sample locations are shown in Figure B-8.

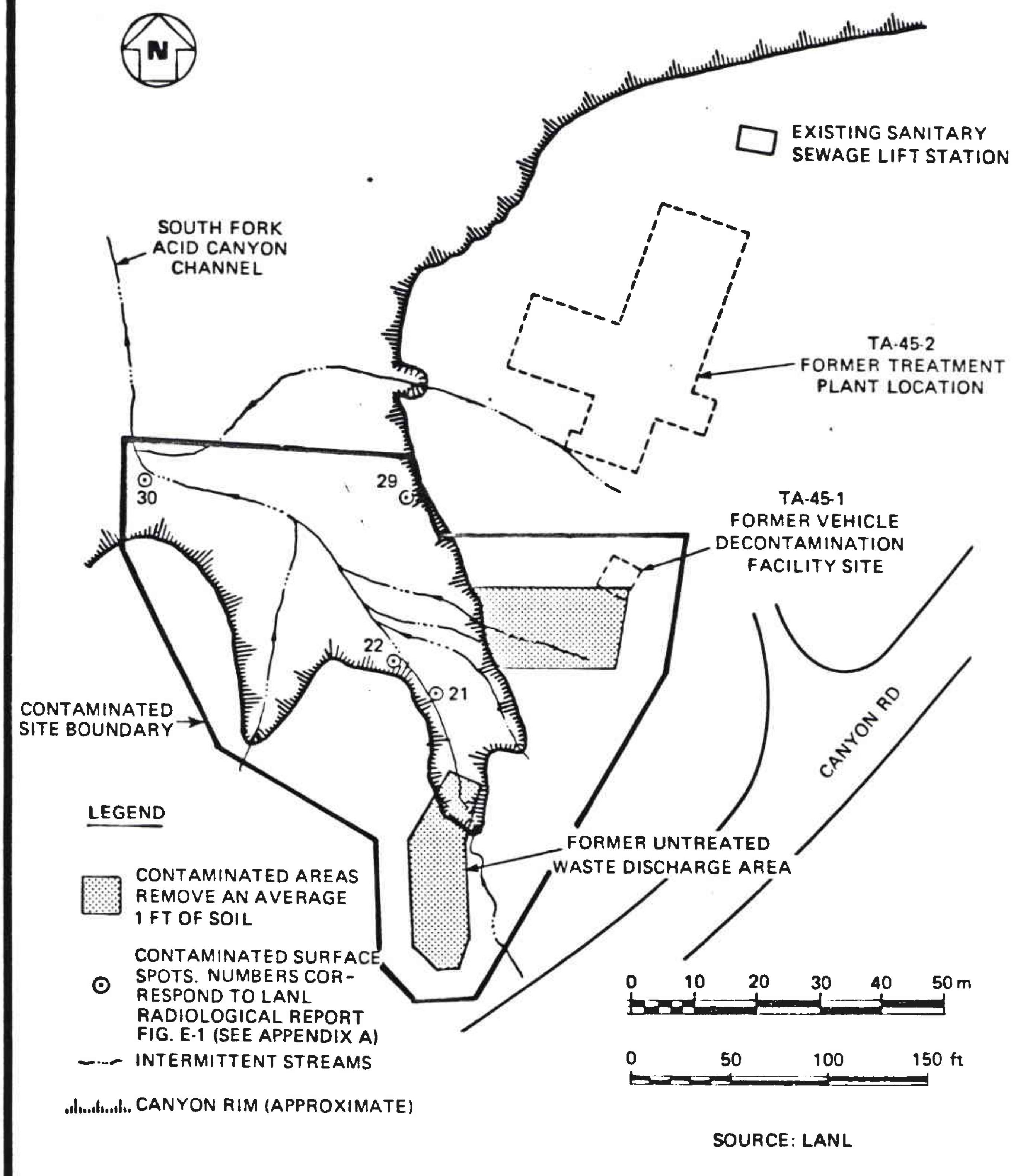


FIGURE B-9 DESIGNATED CONTAMINATED SITE AREA

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## APPENDIX B REFERENCES

1. "Radiological Survey of the Site of a Former Radioactive Liquid Waste Treatment Plant (TA-45) and the Effluent Receiving Areas of Acid, Pueblo, and Los Alamos Canyons, Los Alamos, NM"; Final Report; for U.S. Department of Energy, Assistant Secretary for Environment, Division of Environmental Control Technology, Washington, D.C.; by Los Alamos Scientific Laboratory, Los Alamos, New Mexico; under Contract W-7405-ENG-36; Draft Report; Report No. DOE/EV-0005/30.

2. R.L. Griggs; "Geology and Ground Water Resources of the Los Alamos Area, New Mexico"; U.S. Geological Survey Water-Supply Paper 1753; Washington, D.C.; 1964.

3. "Earthquake Information Bulletin"; Vol 7; No. 3; U.S. Department of the Interior, U.S. Geological Survey; May to June 1975.

4. Title 10, Code of Federal Regulations, Part 20, Appendix B; U.S. Government Printing Office; Washington, D.C.; 1980.

# APPENDIX C

## BASIC REMEDIAL ACTION ALTERNATIVES AND PROPOSED OPTIONS

# BASIC REMEDIAL ACTION ALTERNATIVES
## AND PROPOSED OPTIONS

The proposed options for remedial action for the contaminated areas at the Acid/Pueblo Canyon site have been formulated based on the site-specific conditions described in Appendix B and on the basic remedial action alternatives that should be considered for any remedial action site. A presentation of the basic alternatives and proposed options follows.

### BASIC REMEDIAL ACTION ALTERNATIVES

There are five basic alternatives for categorizing the remedial actions for contaminated properties. From these five basic alternatives, three options for remedial action have been formulated for the contaminated areas of the site in Acid/Pueblo Canyon. The five basic alternatives are briefly defined in the paragraphs that follow.

#### Basic Alternative I - No Action

In this alternative, no action is taken at all; consequently, the contaminated property remains unchanged. This basic alternative is one of the possible courses of action that requires consideration based on the Council of Environmental Quality regulations(1). This alternative is the basis against which population health effects analyses can be compared, and also the basis for comparison of current environmental impacts with the impacts that would result from implementation of other alternatives.

#### Basic Alternative II - Minimal Action

Minimal action implies that no remedial actions are taken to clean up the contamination. Minimal action involves only those measures that effectively limit public exposure to radioactive sources, such as restricting access to a contaminated property.

In general, the minimal action alternative requires that the property be purchased by a government agency and held in perpetuity, secured by fencing and posted with appropriate warning signs, maintained, and radiologically monitored periodically for water, soil, and air contamination.

#### Basic Alternative III - Stabilization/Entombment

Stabilization refers to the covering of a contaminated area with a required amount of compacted clean soil. Entombment involves the total encapsulation of contaminated materials with a permanent casing such as concrete.

Access to a site could be restricted, as could uses for the site. Periodic radiological monitoring of the environment normally is required, as is periodic maintenance.

Basic Alternative IV - Partial Decontamination

Partial decontamination involves remedial action to remove or contain easily accessible active or potentially active sources to prevent further contamination. For open lands, for example, surface contamination could be removed to prevent spreading. Highly radioactive soil could be removed, leaving soil with lower levels of contamination to be removed later. Contaminated ditches and streams could be cleaned up to stop the spread of contamination, leaving adjacent soil to be removed at a later time.

Access to the partially decontaminated areas of the site could be restricted. A program of surveillance and maintenance normally would be required to ensure containment of contamination.

Basic Alternative V - Decontamination and Restoration

Decontamination and restoration remedial actions are formulated so that all above-criteria contamination is removed from a property in order to make it available for unrestricted use. Contaminated soils are excavated to the extent needed to meet the appropriate decontamination criteria. All contaminated debris from buildings and contaminated soils are transported safely to an appropriate disposal site. Restoration of the property follows after completion of decontamination efforts. Certification by ASEP of decontamination then allows unrestricted use of the property.

REMEDIAL ACTION OPTIONS

The three proposed options formulated for remedial action at the contaminated site area are a result of applying the concepts inherent in the basic alternatives to the specific conditions of the contaminated areas of the Acid/Pueblo site.

Basic Alternative I (No Action) is the basis for a proposed option for the Acid/Pueblo site.

Basic Alternative II (Minimal Action) can be used as a foundation for a proposed option for the contaminated site. The property is presently in public ownership and access can be restricted by fencing.

Basic Alternative III (Stabilization/Entombment) is not used as a basis for a proposed option for the Acid/Pueblo site. Stabilization or entombment of the contamination in the steep sections of Acid Canyon is impractical and would be more costly than decontamination and restoration. For these reasons, this alternative was not considered to be a viable option for the contaminated site.

Basic Alternative IV (Partial Decontamination) appears to offer no advantages. Partial decontamination is an interim measure used to remove small amounts of highly contaminated materials while leaving greater volumes of lower level contamination to be removed at a later time. This approach is not practical at the Acid/Pueblo site due to the accessibility of the contamination and the small volumes involved. It would cost more to remove a part of the contamination and fence the site than it would to decontaminate to criteria levels.

Basic Alternative V (Decontamination and Restoration) is considered to be a practical approach for an option for the contaminated site. An option based on this alternative would allow unrestricted use of the site property.

Option A - No Action

In this option no action would be taken at the Acid/Pueblo Canyon site, which means the property would remain unchanged and no costs would be incurred. The public would be informed that no action would be taken. Implementation of Option A must be considered so that the impacts of the current conditions can be compared with impacts that would result from implementation of other options. The impacts are addressed in the LANL environmental analysis report(2).

Option B - Minimal Action

With Option B, contaminated areas would be left undisturbed. Permanent federal (or county) ownersnip or control of the site area would be required. The contaminated site would be fenced to restrict access. Radiation warning signs would be installed around the 1-acre site boundary to prevent public entrance. Radiological monitoring would be required before and during implementation. After implementation, monitoring would be required on an annual basis and surveillance on a quarterly basis. The site would not be available for use. A crew of four and 10 to 12 days would be required to complete the remedial action.

Option C - Decontamination and Restoration with Disposal

Under this option, the contamination on top of the mesa would be removed and transported to a disposal site. The estimated 300 $yd^3$ of contaminated soils (bulk) above criteria would be removed from the former vehicle decontamination facilty and around the former untreated waste effluent outfall.

No fencing or periodic maintenance would be required. Radiological monitoring would not be required except before, during, and immediately after completion of the remedial actions to ensure that all of the above-guideline contamination was removed. After remedial actions are completed, the ASEP would certify the site for unrestricted use. A crew of six could complete the remedial actions in 10 to 12 days.

## APPENDIX C REFERENCES

1. "Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act"; Council on Environmental Quality, Executive Office of the President; 43FR55987-56007, 40CFR, Parts 1500-1508; Nov 29, 1978.

2. "Environmental Analysis of the Acid/Pueblo Canyon Site, Los Alamos, New Mexico"; Los Alamos National Laboratory; Los Alamos, New Mexico; 1982.

# APPENDIX D

# RADIOLOGICAL DATA

## APPENDIX D

## DATA

This Appendix contains the detailed results of the measurements performed on the soil and sediment samples collected for the survey. The results are organized into tables by strata or sub-strata and identified by individual sample numbers. The sample numbers may be keyed to sample locations shown on the maps in Figs. E-1 through E-6 and E-8 in Appendix E. The last table in this Appendix, D-XXIII, contains information about the location of samples in active channel, inactive channel, or banks for the canyon transects.

### TABLE D-I

### TREATMENT PLANT SITE
### GROSS-ALPHA ACTIVITY AND GROSS BETA ACTIVITY
### IN THE 0-5-cm SOIL LAYER

| Location | Gross α (pCi/g) | Gross β (relative) |
|---|---|---|
| 1 | 40 | 4 |
| 2 | 90 | 4 |
| 3 | 60 | 4 |
| 4 | 30 | 9 |
| 5 | 40 | 4 |
| 12 | 52490 | 17 |
| 9 | 87890 | 25 |
| 8 | 10010 | 8 |
| 6 | 1960 | 60 |
| 7 | 670 | 12 |
| 16 | 100 | 68 |
| 15 | 20 | 4 |
| 17 | 20 | 4 |
| 45-2 | 90 | 1 |
| 45-3 | 150 | 4 |

## TABLE D-II

### TREATMENT PLANT SITE
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES IN THE 0-5-cm SOIL LAYER

| Location | pCi/g | | | | | | | | µg/g | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $^{90}$Sr | $^{137}$Cs | Gross α | $^{239}$Pu | $^{238}$Pu | $^{241}$Pu[a] | $^{241}$Am | $^{226}$Ra | Total Uranium | $^{232}$Th |
| 2 | 0.90 | 1.85 | 90 | 63.90 | 0.26 | --- | 0.93 | 1.20 | 4.7 | 13 |
| 3 | 0.50 | 2.19 | 60 | 61.40 | 0.08 | --- | 1.46 | 1.28 | 5.5 | 9.7 |
| 12 | 1.0 | 10.70 | 52 490 | 86 900.0 | 326.0 | 7970 | 55.0 | 1.20 | 79.0 | 71 |
| 9 | 0.9 | 1.13 | 87 890.0 | 163 000.0 | 696.0 | 14 900 | 1200.0 | 0.0 | 122.0 | 93 |
| 8 | 2.4 | 2.26 | 10 010 | 16 300.0 | 70.4 | 1620 | 126.0 | 2.0 | 20.0 | --- |
| 6 | 5.1 | 36.0 | 1960 | 3690.0 | 26.4 | --- | 106.0 | 1.8 | 600.0 | 75 |
| 7 | 1.8 | 25.1 | 670 | 433.0 | 2.72 | --- | 10.0 | 1.24 | 105.0 | 20 |
| 16 | 229.0 | 176.0 | 100 | 41.9 | 0.26 | --- | --- | 0.87 | 126.0 | 11.7 |
| 15 | 1.50 | 1.82 | 20 | 0.61 | 0.0 | --- | --- | 0.94 | 4.4 | 12.9 |
| 17 | 0.79 | 1.22 | 20 | 0.22 | 0.023 | --- | --- | 1.03 | 4.8 | 11.5 |
| 45-2 | 0.52 | 0.29 | 90 | 43.9 | 0.25 | --- | --- | 0.68 | 1.5 | 19.2 |
| 45-3 | 0.24 | 0.13 | 150 | 259.0 | 1.14 | --- | --- | 0.56 | 3.5 | 12.1 |

[a] $^{241}$Pu, a beta emitter, is included here because it is a precursor of $^{241}$Am, an alpha emitter. Moreover, $^{241}$Pu betas are too weak to register on our gross-beta counter.

TABLE D-III

TREATMENT PLANT SITE
GROSS-ALPHA ACTIVITY AND GROSS-BETA ACTIVITY
IN THE 0-25-cm SOIL LAYER

| Location | Gross $\alpha$ (pCi/g) | Gross $\beta$ (relative) |
|---|---|---|
| A1 | 40 | 2 |
| A2 | 20 | 4 |
| A3 | 30 | 3 |
| A4 | 30 | 2 |
| A5 | 40 | 4 |
| A6 | 40 | 3 |
| A7 | 20 | 2 |
| B1 | 30 | 4 |
| B2 | 30 | 3 |
| B8 | 40 | 4 |
| C1 | 80 | 3 |
| C2 | 40 | 1 |
| C3 | 40 | 3 |
| D2 | 60 | 1 |
| D3 | 40 | 0 |
| E2 | 80 | 4 |
| E3 | 60 | 3 |
| E6 | 30 | 3 |
| E7 | 40 | 1 |
| F3 | 40 | 2 |
| F4 | 30 | 1 |
| F5 | 20 | 3 |

## TABLE D-IV
## TREATMENT PLANT SITE
## RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
## IN THE 0-25-cm SOIL LAYER

| Location | pCi/g | | | | | | µg/g | |
|---|---|---|---|---|---|---|---|---|
| | $^{90}Sr$ | $^{137}Cs$ | Gross $\alpha$ | $^{239}Pu$ | $^{238}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| A1 | 0.31 | 0.28 | 40 | 0.12 | 0.0 | 1.15 | 2.5 | 13.7 |
| A6 | 0.29 | 0.45 | 40 | 0.18 | 0.006 | 0.70 | 2.6 | 13.9 |
| A8 | 0.62 | 0.99 | --- | 0.15 | 0.10 | 0.52 | 2.0 | 13.4 |
| B1 | 0.45 | 0.41 | 30 | 0.42 | 0.0 | 1.13 | 4.2 | 14.9 |
| C1 | 0.61 | 0.31 | 80 | 34.0 | 0.32 | 0.94 | 2.4 | 13.7 |
| C5 | 0.27 | 0.14 | --- | 0.45 | 0.01 | 0.61 | 2.3 | 13.3 |
| D1 | 183.0 | 77.6 | --- | 38.2 | 0.25 | 0.75 | 110.0 | 12.1 |
| E2 | 0.41 | 0.23 | 80 | 0.61 | 0.012 | 1.12 | 3.4 | 12.4 |
| F2 | 0.33 | 0.88 | --- | 0.29 | 0.005 | 0.34 | 1.7 | 10.2 |
| 14 | --- | --- | 20 | --- | --- | --- | --- | --- |
| 14a | --- | --- | 50 | --- | --- | --- | --- | |

## TABLE D-V

### TREATMENT PLANT SITE GROSS-ALPHA AND GROSS-BETA ACTIVITY IN THE 0-120-cm SOIL LAYER

| Location | Depth (cm) | Gross α (pci/g) | Gross β (relative) |
|---|---|---|---|
| 45-1 | 0-120 | 30 | 3 |
| 45-4 | 0-120 | 20 | 3 |
| 45-5 | 0-120 | 50 | 4 |
| 45-6 | 0-120 | 20 | 4 |
| 45-7 | 0-120 | 60 | 3 |
| 45-8 | 0-120 | 50 | 3 |
| 45-9 | 0-120 | 10 | 4 |
| 45-10 | 0-120 | 60 | 4 |
| 45-11 | 0-120 | 50 | 2 |
| 45-12 | 0-120 | 50 | 5 |
| 45-13 | 0-120 | 20 | 2 |
| 45-14 | 0-120 | 50 | 4 |
| 45-15 | 0-120 | 30 | 2 |
| 45-16 | 0-120 | 80 | 3 |
| 45-17 | 0-120 | 60 | 2 |
| 45-18 | 0-120 | 60 | 3 |
| 45-19 | 0-120 | 40 | 1 |
| 45-20 | 0-120 | 60 | 2 |
| 45-21 | 0-120 | 50 | 2 |
| 45-22 | 0-120 | 40 | 3 |
| 45-23 | 0-120 | 40 | 6 |
| 45-24 | 0-120 | 40 | 7 |
| 45-25 | 0-120 | 40 | 2 |
| 45-26 | 0-120 | 30 | 4 |
| B3-1 | 0-91 | 40 | 2 |
| B3-2 | 90-180 | 80 | 3 |
| B4-1 | 90-180 | 60 | 3 |
| B5-1 | 0-60 | 40 | 2 |
| B5-2 | 60-120 | 40 | 1 |
| B6-1 | 0-60 | 40 | 3 |
| B6-2 | 60-120 | 40 | 2 |
| C5-1 | 0-60 | 60 | 2 |
| C5-2 | 60-120 | 30 | 1 |

| Location | Depth (cm) | Gross α (pCi/g) | Gross β (relative) |
|---|---|---|---|
| C6-1 | 0-60 | 40 | 1 |
| C6-2 | 60-120 | 50 | 3 |
| C7-1 | 90-180 | 40 | 3 |
| C7-2 | 60-120 | 60 | 2 |
| D7-1 | 0-60 | 50 | 1 |
| D7-2 | 60-120 | 50 | 3 |
| A-1 | 0-60 | (lost) | (lost) |
| A-2 | 60-120 | 20 | 3 |
| B-1 | 0-60 | 40 | 3 |
| B-2 | 60-120 | 30 | 1 |
| Ba-1 | 0-60 | 10 | 2 |
| Ba-2 | 60-120 | 20 | 2 |
| C-1 | 0-60 | 60 | 3 |
| C2 | 60-120 | 30 | 3 |
| D-1 | 0-60 | 60 | 4 |
| D-2 | 60-120 | 50 | 2 |
| Ea-1 | 0-60 | 50 | 3 |
| Ea-2 | 60-120 | 40 | 1 |
| Eb-1 | 0-60 | 40 | 3 |
| Eb-2 | 60-120 | 60 | 3 |
| F-1 | 0-490 | 40 | 2 |
| PA-1 | 0-150 | 40 | 2 |
| PB-A-1 | 0-150 | 70 | 2 |
| PB-B-1 | 0-150 | 70 | 1 |
| PC-1 | 0-150 | 40 | 2 |
| HB-1 | 0-60 | 60 | 3 |
| HB-2 | 60-120 | 40 | 2 |
| SB-1 | 0-60 | 10 | 3 |
| SB-2 | 60-120 | 40 | 1 |
| SP1-1 | 0-60 | 30 | 2 |
| SP1-2 | 60-120 | 40 | 2 |
| SP2a-1 | 0-370 | 40 | 3 |
| SP2b-1 | 0-150 | 40 | 2 |

## TABLE D-VI

### TREATMENT PLANT SITE
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
### IN THE 0-120-cm SOIL LAYER

| | pCi/g | | | | | | µg/g | |
|---|---|---|---|---|---|---|---|---|
| Location | $^{90}Sr$ | $^{137}Cs$ | Gross $\alpha$ | $^{239}Pu$ | $^{238}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| 45-1 | 2.85 | 2.23 | 30 | 11.7 | 0.13 | 1.05 | 2.7 | 14.5 |
| 45-4 | 0.50 | 0.73 | 20 | 0.20 | 0.006 | 0.78 | 2.0 | 9.6 |
| 45-5 | 2.58 | 1.76 | 50 | 0.24 | 0.0 | 0.96 | 2.0 | 11.0 |
| 45-6 | 0.43 | 0.16 | 20 | 0.15 | 0.006 | 1.16 | 2.2 | 12.3 |
| 45-7 | 0.39 | 0.34 | 60 | 0.26 | 0.010 | 1.02 | 2.6 | 12.4 |
| 45-9 | 1.05 | 0.96 | 10 | 4.04 | 0.063 | 1.07 | 2.9 | 11.7 |
| 45-13 | 0.55 | 0.18 | 20 | 0.12 | 0.003 | 0.68 | 3.8 | 9.1 |
| 45-16 | 0.42 | 0.21 | 80 | 35.2 | 0.33 | 0.78 | 2.1 | 12.1 |
| 45-18 | 0.56 | 0.18 | 60 | 2.00 | 0.036 | 0.72 | 3.5 | 10.9 |
| 45-22 | 0.52 | 0.25 | 40 | 2.64 | 0.032 | 0.92 | 3.8 | 11.6 |
| 45-24 | 9.62 | 3.20 | 40 | 24.4 | 0.27 | 0.39 | 36.0 | 11.4 |
| 45-26 | 0.51 | 0.44 | 30 | 0.26 | 0.01 | 0.97 | 2.5 | 11.7 |
| PB-b-1 | 0.24 | 0.07 | 70 | 12.3 | 0.15 | 1.03 | 2.0 | 11.9 |
| F-1 | 0.14 | 0.0 | 40 | 1.56 | 0.017 | 0.76 | 1.6 | 13.1 |

## TABLE D-VII

### TREATMENT PLANT SITE
### GROSS-ALPHA AND GROSS-BETA ACTIVITY
### IN THE 120-240-cm SOIL LAYER

| Location | Depth (cm) | Gross $\alpha$ (pCi/g) | Gross $\beta$ (relative) |
|---|---|---|---|
| B3-2 | 90-180 | 80 | 3 |
| B4-1 | 0-180 | 60 | 3 |
| B5-3 | 120-180 | 20 | 2 |
| B6-3 | 120-180 | 20 | 1 |
| C5-3 | 120-180 | 120 | 1 |
| C5-4 | 180-240 | 90 | 0 |
| C6-3 | 120-180 | 30 | 3 |
| C6-4 | 180-240 | 60 | 3 |
| C7-3 | 120-180 | 30 | 1 |
| C7-4 | 180-240 | 60 | 2 |
| D7-3 | 120-180 | 20 | 3 |
| D7-4 | 180-240 | 60 | 3 |
| A-3 | 120-180 | 40 | 2 |
| A-4 | 180-240 | 50 | 3 |
| Ba-3 | 120-180 | 50 | 1 |
| Ba-4 | 180-240 | 30 | 4 |
| C-3 | 120-180 | 40 | 1 |
| C-4 | 180-240 | 20 | 2 |
| D-3 | 120-180 | 40 | 4 |
| D-4 | 180-240 | 80 | 3 |
| Eb-3 | 120-240 | 30 | 3 |
| F-1 | 0-490 | 40 | 2 |
| PA-2 | 150-300 | 70 | 3 |
| PB-A-2 | 150-300 | 30 | 2 |
| PC-2 | 150-300 | 30 | 3 |
| HB-3 | 120-180 | 40 | 2 |
| HB-4 | 180-240 | 30 | 1 |
| SB-3 | 120-180 | 40 | 2 |
| SB-4 | 180-240 | 30 | 1 |
| SP1-3 | 120-180 | 60 | 3 |
| SP1-4 | 180-240 | 50 | 2 |
| SP2a-1 | 0-365 | 40 | 3 |
| SP2b-2 | 150-360 | 30 | 2 |

## TABLE D-VIII

### TREATMENT PLANT SITE
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
### IN THE 120-240-cm SOIL LAYER

| | | pCi/g | | | | | | μg/g | |
|---|---|---|---|---|---|---|---|---|---|
| Location | Depth | $^{90}$Sr | $^{137}$Cs | Gross α | $^{239}$Pu | $^{238}$Pu | $^{226}$Ra | Total Uranium | $^{232}$Th |
| A-3 | 120-180 | 0.11 | 0.0 | 40 | 0.0 | 0.0 | 0.94 | 1.8 | 13.5 |
| Ba-3 | 120-180 | 0.0 | 0.0 | 50 | 0.11 | 0.006 | 0.84 | 1.8 | 14.0 |
| C-3 | 120-180 | 0.08 | 0.0 | 40 | 0.25 | 0.005 | 1.02 | 2.7 | 12.0 |
| D-3 | 120-180 | 0.18 | 0.0 | 40 | 5.95 | 0.08 | 0.69 | 1.3 | 10.5 |
| Eb-3 | 120-140 | 0.0 | 0.0 | 30 | 0.046 | 0.0 | 1.00 | 1.5 | 11.9 |
| F-1 | 0-490 | 0.14 | 0.0 | 40 | 1.56 | 0.017 | 0.76 | 1.6 | 13.1 |
| PB-A-2 | 150-300 | 0.14 | 0.0 | 30 | 0.028 | 0.004 | 0.75 | 0.7 | 8.5 |
| PC-2 | 150-300 | 0.14 | 0.0 | 30 | 0.18 | 0.0 | 0.87 | 1.5 | 10.7 |
| HB-3 | 120-180 | 0.09 | 0.0 | 40 | 0.36 | 0.018 | 1.37 | 1.5 | 11.6 |
| SB-3 | 120-180 | 0.17 | 0.0 | 40 | 1.82 | 0.041 | 0.94 | 1.8 | 13.2 |

## TABLE D-IX

## TREATMENT PLANT SITE
## GROSS-ALPHA AND GROSS-BETA ACTIVITY
## IN THE 240-850-cm SOIL LAYER

| Location | Depth | Gross $\alpha$ (pCi/g) | Gross $\beta$ (relative) |
|---|---|---|---|
| C5-5 | 240-300 | 90 | 1 |
| C7-5 | 240-300 | 40 | 3 |
| C7-6 | 300-360 | 60 | 2 |
| C7-7 | 360-420 | 50 | 2 |
| C7-8 | 420-480 | 50 | 3 |
| C7-9 | 480-540 | 50 | 3 |
| C7-10 | 540-600 | 40 | 3 |
| C7-11 | 600-660 | 60 | 3 |
| C7-12 | 660-720 | 60 | 4 |
| D7-5 | 240-300 | 50 | 2 |
| D7-6 | 300-390 | 60 | 2 |
| A-5 | 240-300 | 30 | 3 |
| A-6 | 300-360 | 40 | 2 |
| Ba-5 | 240-300 | 20 | 3 |
| Ba-6 | 300-390 | 40 | 3 |
| C-5 | 240-300 | 40 | 4 |
| C-6 | 300-360 | 30 | 4 |
| D-5 | 240-300 | 40 | 4 |
| F-1 | 0-490 | 40 | 2 |
| PA-4 | 450-600 | 50 | 1 |
| PA-5 | 600-750 | 40 | 2 |
| PB-A-3 | 300-450 | 30 | 2 |
| PB-A-4 | 450-600 | 50 | 1 |
| PB-A-5 | 600-750 | 30 | 3 |
| PB-B-3 | 300-450 | 90 | 2 |
| PB-B-4 | 450-600 | 70 | 2 |
| PC-3 | 300-450 | 20 | 2 |
| PC-4 | 450-600 | 40 | 1 |
| PC-5 | 600-750 | 50 | 1 |
| SB-5 | 240-300 | 30 | 3 |
| SB-6 | 300-360 | 40 | 3 |
| SP1-5 | 240-300 | 40 | 2 |
| SP1-6 | 300-360 | 40 | 2 |
| SP2a-1 | 0-360 | 40 | 3 |
| SP2a-2 | 360-670 | 20 | 2 |
| SP2b-2 | 150-360 | 30 | 2 |

TABLE D-X

TREATMENT PLANT SITE
RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
IN THE 240-850-cm SOIL LAYER

| | | pCi/g | | | | | | μg/g | |
|---|---|---|---|---|---|---|---|---|---|
| Location | Depth | $^{90}Sr$ | $^{137}Cs$ | Gross α | $^{239}Pu$ | $^{238}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| F-1 | 0-490 | 0.14 | 0.0 | 40 | 1.56 | 0.017 | 0.76 | 1.6 | 13.1 |
| PA-3 | 300-450 | 0.20 | 0.04 | --- | 0.95 | 0.027 | 0.36 | 1.7 | 11.92 |
| PA-4 | 450-600 | 0.16 | 0.0 | 50 | 0.062 | 0.0 | 0.91 | 1.8 | 10.09 |
| PA-5 | 600-750 | 0.40 | 0.90 | 40 | 0.15 | 0.0 | 0.90 | 1.7 | 11.5 |
| PBA-3 | 300-450 | 0.09 | 0.0 | 30 | 0.080 | 0.012 | 0.96 | 1.6 | 12.56 |
| PBA-4 | 450-600 | 0.0 | 0.0 | 50 | 0.160 | 0.011 | 0.75 | 1.3 | 10.55 |
| PBA-5 | 600-750 | 0.0 | 0.0 | 30 | 0.074 | 0.0 | 0.80 | 2.2 | 11.83 |
| PB-B-3 | 300-450 | 0.0 | 0.0 | 90 | 0.0 | 0.0 | 1.10 | 2.2 | 15.59 |
| PB-B-4 | 450-600 | 0.0 | 0.0 | 70 | 0.032 | 0.0 | 0.64 | 1.3 | 7.24 |
| PC-3 | 300-450 | 0.0 | 0.0 | 20 | 0.011 | 0.0 | 0.80 | 1.6 | 11.56 |
| PC-4 | 450-600 | 0.17 | 0.0 | 40 | 0.033 | 0.003 | 0.88 | 1.5 | 10.73 |
| PC-5 | 600-750 | 0.10 | 0.0 | 50 | 0.029 | 0.004 | 1.03 | 1.4 | 13.48 |
| SP1-5 | 240-300 | 0.35 | 0.0 | 40 | 0.470 | 0.012 | 0.89 | 1.3 | 10.73 |
| SP2a-2 | 360-670 | 0.10 | 0.05 | 20 | 0.171 | 0.0 | 0.59 | 1.1 | 6.6 |

## TABLE D-XI

### ACID CANYON
### GROSS-ALPHA AND GROSS-BETA ACTIVITY
### IN THE 0-5-cm SOIL LAYER

| Location | Gross $\alpha$ (pCi/g) | Gross $\beta$ (relative) |
|---|---|---|
| 18 | 20 | 3 |
| 19 | 20 | 1 |
| 20 | 580 | 5 |
| 25 | 60 | 5 |
| 26 | 50 | 6 |
| 27 | 40 | 4 |
| 28 | 40 | 3 |
| 23 | 20 | 9 |
| 24 | 30 | 6 |
| 21 | 460 | 5 |
| 29 | 110 | 2 |
| 30 | 80 | 3 |

## TABLE D-XII

### ACID CANYON
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
### IN THE 0-5-cm SOIL LAYER

| Location | pCi/g | | | | | | | $\mu$g/g | |
|---|---|---|---|---|---|---|---|---|---|
| | $^{90}$Sr | $^{137}$Cs | Gross $\alpha$ | $^{239}$Pu | $^{238}$Pu | $^{241}$Am | $^{226}$Ra | Total Uranium | $^{232}$Th |
| 20 | 1.1 | 0.79 | 580 | 629.0 | 3.13 | 43.4 | 1.1 | 10.0 | 13 |
| 25 | 0.70 | 0.20 | 60 | 33.5 | 0.15 | 1.67 | 1.30 | 3.0 | 15 |
| 26 | 4.5 | 12.1 | 50 | 38.4 | 0.10 | 1.82 | 1.10 | 3.7 | 9.7 |
| 27 | 0.4 | 0.54 | 40 | 8.20 | 0.0 | 0.41 | 1.90 | 3.9 | 14 |
| 28 | 0.4 | 1.64 | 40 | 5.20 | 0.04 | 0.33 | 2.00 | 2.8 | 13 |

## TABLE D-XIII

### ACID CANYON
### GROSS-ALPHA ACTIVITY IN THE
### 0-25-cm SOIL LAYER

| Location | Depth (cm) | pCi/g |
|---|---|---|
| 24 (stream channel) | 0-15 | 40 |
| 24 (banks) | 0-15 | 50 |
| 32 (stream channel) | 0-30 | 70 |
| 32 (banks) | 0-30 | 40 |
| 33 (stream channel) | 0-30 | 70 |
| 33 (banks) | 0-30 | 60 |

## TABLE D-XIV

### ACID CANYON
### TRANSECT AC 20 AT STATION 33
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
### IN THE 0-25-cm SOIL LAYER

| | pCi/g | | | | | | μg/g | |
|---|---|---|---|---|---|---|---|---|
| Location | $^{90}Sr$ | $^{137}Cs$ | Gross α | $^{238}Pu$ | $^{239}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| North bank | 0.78 | 1.05 | 40 | 12.5 | 0.83 | 0.77 | 0.9 | 7.24 |
| Active channel | 1.69 | 1.28 | 40 | 15.8 | 0.095 | 0.86 | 1.5 | 9.35 |
| South bank | 0.23 | 0.25 | 10 | 0.11 | 0.0 | 0.77 | 1.8 | 9.54 |

## TABLE D-XV

### MIDDLE PUEBLO CANYON
### GROSS-ALPHA AND GROSS-BETA ACTIVITY
### IN THE 0-25-cm SOIL LAYER

| Location | Gross $\alpha$ (pCi/g) | Gross $\beta$ (relative) |
|---|---|---|
| 15900-0 | 30 | 5 |
| 15900-1 | 10 | 3 |
| 15900-2 | 40 | 3 |
| 15500-0 | 100 | 3 |
| 15500-1 | 0 | 5 |
| 15500-2 | 40 | 3 |
| 14950-2 | 30 | 3 |
| 14150-0 | 30 | 3 |
| 14150-1 | 40 | 10 |
| 14150-2 | 40 | 12 |
| 13650-1 | 20 | 2 |
| 13650-2 | 20 | 3 |
| OAPII-1 | 0 | 3 |
| OAPII-2 | 0 | 5 |
| OAPII-3 | 0 | 4 |
| OAPII-4 | 0 | 4 |
| OAPII-5 | 0 | 4 |
| OAPII-6 | 0 | 4 |
| OAPII-7 | 0 | 4 |
| OAPII-8 | 0 | 5 |
| OAPII-9 | 10 | 6 |
| OAPII-10 | 0 | 3 |
| OAPII-11 | 0 | 6 |
| OAPII-12 | 0 | 3 |
| OAPII-13 | 0 | 3 |
| OAPII-14 | 0 | 4 |

## TABLE D-XVI

### MIDDLE PUEBLO CANYON
### RADIOLOGICAL ANALYSIS OF SELECTED SOIL SAMPLES
### IN THE 0-25-cm SOIL LAYER

| | pCi/g | | | | | | | μg/g | |
|---|---|---|---|---|---|---|---|---|---|
| Location | $^{90}Sr$ | $^{137}Cs$ | Gross α | $^{238}Pu$ | $^{239}Pu$ | $^{241}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| 15900-0 | 0.30 | 0.30 | 30 | 0.072 | 0.016 | --- | 1.64 | 2.9 | 17.61 |
| 15900-1 | 0.71 | 0.43 | 10 | 3.99 | 0.018 | --- | 1.64 | 0.9 | 8.10 |
| 15900-2 | 0.64 | 0.46 | 40 | 4.46 | 0.052 | --- | 0.69 | 1.6 | 10.45 |
| 15500-0 | --- | --- | 100 | 87.90 | 0.600 | 52 | --- | --- | --- |
| 14150-0 | 0.74 | 0.81 | 30 | 8.72 | 0.060 | 1.5 | 1.62 | 2.8 | 13.20 |
| 14150-1 | 0.22 | 0.25 | 40 | 1.35 | 0.013 | --- | 0.82 | 1.3 | 7.51 |
| 14150-2 | 0.25 | 0.20 | 40 | 0.669 | 0.004 | --- | 0.96 | 2.2 | 11.37 |
| OAPII-1 | --- | --- | 0 | 1.620 | 0.004 | --- | --- | --- | --- |
| OAPII-2 | --- | --- | 0 | 1.000 | 0.0 | --- | --- | --- | --- |
| OAPII-3 | --- | --- | 0 | 0.910 | 0.004 | --- | --- | --- | --- |
| OAPII-4 | --- | --- | 0 | 0.127 | 0.001 | --- | --- | --- | --- |
| OAPII-5 | --- | --- | 0 | 0.570 | 0.007 | --- | --- | --- | --- |
| OAPII-6 | --- | --- | 0.0 | 0.770 | 0.025 | --- | --- | --- | --- |
| OAPII-7 | --- | --- | 0 | 0.430 | 0.0 | --- | --- | --- | --- |
| OAPII-8 | --- | --- | 0 | 0.140 | 0.0 | --- | --- | --- | --- |
| OAPII-9 | --- | --- | 10 | 3.300 | 0.033 | --- | --- | --- | --- |
| OAPII-10 | --- | --- | 0 | 0.140 | 0.0 | --- | --- | --- | --- |
| OAPII-11 | --- | --- | 0 | 0.810 | 0.0 | --- | --- | --- | --- |
| OAPII-12 | --- | --- | 0 | 0.270 | 0.001 | --- | --- | --- | --- |
| OAPII-13 | --- | --- | 0 | 0.930 | 0.0 | --- | --- | --- | --- |
| OAPII-14 | --- | --- | 0 | 1.190 | 0.006 | --- | --- | --- | --- |

## TABLE D-XVII

### LOWER PUEBLO CANYON
### GROSS-ALPHA AND GROSS-BETA ACTIVITY
### IN THE 0-25-cm SOIL LAYER

| Location | Gross α (pCi/g) | Gross β (relative) |
|---|---|---|
| 13150-0 | 30 | 4 |
| 13150-1 | 0 | 4 |
| 13150-2 | 20 | 4 |
| 12850-2 | 30 | 2 |
| 12850-3 | 30 | 4 |
| APII5-0 | 40 | 4 |
| APII5-1 | 10 | 5 |
| APII5-2 | 20 | 4 |
| APII10-0 | 20 | 5 |
| APII10-1 | 30 | 5 |
| APII10-2 | 10 | 5 |
| 12650-0 | 40 | 3 |
| 12650-1 | 10 | 3 |
| 12650-2 | 10 | 3 |
| 12650-3 | 10 | 5 |
| 11850-0 | 40 | 3 |
| 11850-1 | 30 | 4 |
| 11850-2 | 20 | 5 |
| 11850-3 | 20 | 5 |
| 11850-4 | 30 | 4 |
| 11550-0 | 20 | 3 |
| 11550-2 | 20 | 3 |
| 10650-0 | 50 | 3 |
| 10650-1 | 20 | 3 |
| 10650-2 | 30 | 3 |
| 10050-2 | 20 | 1 |
| 10050-3 | 0 | 3 |
| 10050-4 | 10 | 2 |
| 10050-5 | 30 | 3 |
| 9650-0 | 30 | 0 |
| 9650-1 | 30 | 2 |
| 9650-2 | 20 | 2 |
| 9650-3 | 40 | 4 |
| 9650-4 | 30 | 3 |
| 8150-0 | 40 | 5 |
| 8150-1 | 20 | 3 |
| 8150-2 | 30 | 4 |
| 8150-3 | 10 | 2 |
| 8150-4 | 20 | 4 |
| 8150-5 | 10 | 3 |
| 8150-6 | 30 | 4 |
| 8150-7 | 10 | 4 |
| 8150-8 | 20 | 2 |
| 7950-0 | 0 | 4 |
| 7950-1 | 0 | 3 |
| 7950-2 | 10 | 3 |
| 7950-3 | 40 | 4 |
| 7650-0 | 20 | 1 |
| 7650-1 | 30 | 0 |
| 7650-2 | 0 | 1 |
| 7650-3 | 20 | 0 |

## TABLE D-XVIII

## LOWER PUEBLO CANYON RADIOLOGICAL ANALYSES OF SELECTED SOIL SAMPLES IN THE 0-25-cm SOIL LAYER

| | pCi/g | | | | | | | μg/g | |
|---|---|---|---|---|---|---|---|---|---|
| Location | $^{90}$Sr | $^{137}$Cs | Gross α | $^{239}$Pu | $^{238}$Pu | $^{241}$Pu | $^{226}$Ra | Total Uranium | $^{232}$Th |
| 13150-0 | 0.68 | 0.84 | 30 | 7.150 | 0.072 | --- | 1.80 | 3.2 | 17.97 |
| 13150-1 | 0.34 | 0.15 | 0 | 0.409 | 0.013 | 1.1 | 1.91 | 4.3 | 17.42 |
| 13150-2 | 0.47 | 0.43 | 20 | 0.720 | 0.018 | --- | 1.79 | 3.4 | 16.23 |
| 11850-0 | 0.90 | 1.50 | 40 | 9.69 | 0.116 | 9.5 | 1.70 | 4.1 | 15.68 |
| 12850-2 | --- | --- | 30 | 6.4 | 0.037 | --- | --- | --- | --- |
| 12850-3 | --- | --- | 30 | 15.5 | 0.077 | --- | --- | --- | --- |
| 12650-0 | --- | --- | 40 | 0.7 | 0.01 | --- | --- | --- | --- |
| 12650-1 | --- | --- | 10 | 1.06 | 0.009 | --- | --- | --- | --- |
| 12650-2 | --- | --- | 10 | 4.89 | 0.026 | --- | --- | --- | --- |
| 12650-3 | --- | --- | 10 | 0.55 | 0.006 | --- | --- | --- | --- |
| APII5-0 | --- | --- | 40 | 10.6 | 0.064 | --- | --- | --- | --- |
| APII5-1 | --- | --- | 10 | 1.90 | 0.017 | --- | --- | --- | --- |
| APII5-2 | --- | --- | 20 | 7.50 | 0.035 | --- | --- | --- | --- |
| APII10-0 | --- | --- | 20 | 8.9 | 0.049 | --- | --- | --- | --- |
| APII10-1 | --- | --- | 30 | 1.97 | 0.013 | --- | --- | --- | --- |
| APII10-2 | --- | --- | 10 | 7.1 | 0.040 | --- | --- | --- | --- |
| 11850-1 | 0.42 | 0.81 | 30 | 5.88 | 0.054 | --- | 1.90 | 3.9 | 17.79 |
| 11850-2 | 0.28 | 0.49 | 20 | 0.94 | 0.019 | --- | 2.20 | 3.8 | 14.03 |
| 11850-3 | 0.22 | 0.17 | 20 | 0.43 | 0.013 | --- | 1.62 | 3.6 | 13.30 |
| 11850-4 | 0.18 | 0.17 | 30 | 1.15 | 0.013 | --- | 1.09 | 2.0 | 10.45 |
| 10650-0 | 0.35 | 0.40 | 50 | 10.8 | 0.064 | 2.2 | 1.50 | 5.7 | 12.29 |
| 10650-1 | 0.12 | 0.0 | 20 | 0.584 | 0.006 | --- | 0.80 | 1.8 | 8.99 |
| 10650-2 | 0.41 | 0.61 | 30 | 3.81 | 0.047 | --- | 1.67 | 3:2 | 15.96 |
| 9650-3 | --- | --- | 40 | 7.14 | 0.100 | 4.0 | --- | --- | --- |
| 8150-0 | 0.94 | 1.75 | 40 | 15.30 | 0.125 | 8.1 | 1.51 | 3.5 | 14.49 |
| 8150-1 | 0.17 | 0.18 | 20 | 0.97 | 0.0 | --- | 1.59 | 1.8 | 15.86 |
| 8150-2 | 0.31 | 0.24 | 30 | 1.00 | 0.010 | --- | 1.12 | 1.3 | 11.74 |
| 8150-3 | 0.12 | 0.06 | 10 | 0.59 | 0.031 | | 0.86 | 1.8 | 6.05 |
| 8150-4 | 0.18 | 0.22 | 20 | 0.91 | 0.0 | --- | 0.74 | 1.6 | 8.99 |
| 8150-5 | 0.18 | 0.13 | 10 | 0.85 | 0.014 | --- | 0.59 | 1.7 | 6.33 |
| 8150-6 | 0.39 | 0.63 | 30 | 4.09 | 0.081 | --- | 0.96 | 2.5 | 13.20 |
| 8150-7 | 0.12 | 0.0 | 10 | 0.35 | 0.0 | --- | 0.60 | 1.9 | 6.33 |
| 8150-8 | 0.34 | 0.42 | 20 | 3.32 | 0.019 | --- | 1.24 | 3.5 | 12.56 |
| 7950-0 | 0.12 | 0.0 | 0 | 0.34 | 0.009 | --- | 0.72 | 2.2 | 5.50 |
| 7950-1 | 0.087 | 0.0 | 0 | 0.27 | 0.0 | --- | 0.42 | 1.1 | 3.48 |
| 7950-2 | 0.16 | 0.11 | 10 | 0.77 | 0.008 | --- | 0.79 | 3.6 | 6.88 |
| 7950-3 | 0.37 | 0.05 | 40 | 9.72 | 0.081 | 4.5 | 1.94 | 3.3 | 15.77 |

## TABLE D-XIX

### LOWER LOS ALAMOS CANYON GROSS-ALPHA AND GROSS-BETA ACTIVITY IN THE 0-25-cm SOIL LAYER

| Location | Gross α (pCi/g) | Gross β (relative) |
|---|---|---|
| 7250-0 | 10 | 4 |
| 7250-1 | 10 | 2 |
| 7250-2 | 10 | 3 |
| 5900-0 | 30 | 1 |
| 5900-1 | 10 | 0 |
| 5900-2 | 20 | 2 |
| 5800-0 | 10 | 5 |
| 5800-1 | 10 | 4 |
| 5800-2 | 10 | 2 |
| 5700-0 | 40 | 0 |
| 5700-1 | 30 | 2 |
| 5700-2 | 10 | 2 |
| 5100-0 | 10 | 1 |
| 5100-1 | 30 | 4 |
| 5100-2 | 30 | 0 |
| 5100-3 | 30 | 1 |
| 5000-0 | 40 | 2 |
| 5000-1 | 40 | 2 |
| 5000-2 | 20 | 2 |
| 5000-3 | 20 | 2 |
| 4300-0 | 20 | 1 |
| 4300-1 | 20 | 1 |
| 3700-0 | 20 | 3 |
| 3700-1 | 20 | 3 |
| 3700-2 | 0 | 4 |
| 3700-3 | 0 | 5 |
| 3200-0 | 20 | 1 |
| 3200-1 | 0 | 4 |
| 3200-2 | 0 | 3 |
| 3200-3 | 0 | 3 |
| 3200-4 | 0 | 4 |
| 3200-5 | 20 | 3 |
| 3100-0 | 20 | 3 |
| 3100-1 | 10 | 1 |
| 3100-2 | 10 | 3 |
| 3100-3 | 20 | 2 |
| 2500-0 | 30 | 1 |
| 2500-1 | 20 | 2 |
| 2500-2 | 10 | 3 |
| 2500-3 | 20 | 1 |
| 2500-4 | 10 | 0 |
| 2500-5 | 40 | 3 |
| 1900-0 | 30 | 4 |
| 1900-1 | 40 | 4 |
| 1900-2 | 30 | 4 |
| 1300-0 | 30 | 3 |
| 1300-1 | 20 | 3 |
| 1300-2 | 50 | 4 |
| 800-0 | 10 | 2 |
| 800-1 | 30 | 3 |
| 800-2 | 10 | 4 |
| 800-3 | 10 | 5 |
| 800-4 | 30 | 3 |
| 400-0 | 30 | 4 |
| 400-1 | 40 | 5 |
| 400-2 | 30 | 5 |
| 0-0 | 20 | 4 |
| 0-1 | 10 | 3 |
| 0-2 | 40 | 3 |

## TABLE D-XX

### LOWER LOS ALAMOS CANYON
### RADIOLOGICAL ANALYSES OF SELECTED SOIL SAMPLES
### IN THE 0-25-cm SOIL LAYER

| | pCi/g | | | | | | | µg/g | |
|---|---|---|---|---|---|---|---|---|---|
| Location | $^{90}Sr$ | $^{137}Cs$ | Gross α | $^{239}Pu$ | $^{238}Pu$ | $^{241}Pu$ | $^{226}Ra$ | Total Uranium | $^{232}Th$ |
| 7250-0 | 0.31 | 0.57 | 10 | 9.30 | 0.027 | 0.9 | 1.74 | 5.3 | 12.10 |
| 7250-1 | 0.24 | 0.64 | 10 | 0.27 | 0.013 | --- | 0.60 | 3.9 | 7.43 |
| 7250-2 | 0.49 | 1.75 | 10 | 3.34 | 0.015 | --- | 1.57 | 5.6 | 16.69 |
| 5900-0 | --- | --- | 30 | 0.880 | 0.007 | --- | --- | --- | --- |
| 5900-1 | --- | --- | 10 | 0.157 | 0.016 | --- | --- | --- | --- |
| 5900-2 | --- | --- | 20 | 5.62 | 0.019 | --- | --- | --- | --- |
| 5800-0 | 0.64 | 1.51 | 10 | 0.27 | 0.0 | --- | 1.51 | 4.7 | 14.76 |
| 5800-1 | 0.30 | 1.30 | 10 | 1.23 | 0.0 | --- | 0.95 | 2.9 | 8.85 |
| 5800-2 | 0.74 | 1.80 | 10 | 0.69 | 0.008 | 13 | 2.16 | 4.7 | 15.68 |
| 5700-0 | --- | --- | 40 | 1.32 | 0.0002 | --- | --- | --- | --- |
| 5700-1 | --- | --- | 30 | 0.67 | 0.011 | --- | --- | --- | --- |
| 5700-2 | --- | --- | 10 | 1.49 | 0.003 | --- | --- | --- | --- |
| 3700-0 | 0.19 | 0.24 | 20 | 0.018 | 0.014 | <3 | 1.44 | 5.1 | 11.00 |
| 3700-1 | 0.18 | 0.20 | 20 | 0.145 | 0.026 | --- | 1.34 | 3.2 | 11.19 |
| 3700-2 | 0.11 | 0.51 | 0 | 0.259 | 0.019 | --- | 0.79 | 2.8 | 7.61 |
| 3700-3 | 0.25 | 0.46 | 0 | 0.510 | 0.014 | --- | 1.29 | 4.2 | 12.56 |
| 3200-0 | 0.23 | 0.33 | 20 | 0.0 | 0.0 | --- | 0.77 | 2.6 | 6.42 |
| 3200-1 | 0.10 | 0.16 | 0 | 0.032 | 0.016 | --- | 0.41 | 5.3 | 12.29 |
| 3200-2 | 0.19 | 0.33 | 0 | --- | 0.0 | --- | 0.78 | 3.6 | 7.36 |
| 3200-3 | 0.0 | 0.14 | 0 | --- | 0.0 | --- | 0.74 | 2.4 | 7.05 |
| 3200-4 | 0.0 | 0.23 | 0 | 0.063 | 0.005 | --- | 0.69 | 1.7 | 5.96 |
| 3200-5 | 0.49 | 1.08 | 20 | 0.133 | 0.012 | --- | 0.89 | 3.0 | 10.64 |
| 2500-5 | --- | --- | 40 | 0.43 | 0.0048 | 1. | --- | --- | --- |
| 800-0 | 0.30 | 0.26 | 10 | 0.117 | 0.0 | --- | 0.89 | 2.8 | 7.38 |
| 800-1 | 0.23 | 0.21 | 30 | 0.097 | 0.008 | --- | 0.92 | 4.5 | 10.55 |
| 800-2 | 0.17 | 0.18 | 10 | 0.051 | 0.0 | --- | 1.27 | 4.5 | 10.18 |
| 800-3 | 0.25 | 0.26 | 10 | 0.066 | 0.004 | --- | 1.09 | 4.0 | 7.57 |
| 800-4 | 0.24 | 0.21 | 30 | 0.075 | 0.0 | --- | 0.90 | 2.0 | 7.54 |

## TABLE D-XXI

## INSTRUMENT READINGS FROM CLIFF SURVEYS

**8 in. Outfall: Line N South of Line M (11/2/77)**

| Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| −9.2[c] | 30 | 801 ± 30 |
| −1.5 | 30 | — |
| 0.0 | 30 | 698 |
| 1.5 | 35 | 713 |
| 3.1 | 35 | 746 |
| 4.6 | 35 | 753 |
| 6.1 | 40 | 701 |
| 7.6 | 40 | 742 |
| 9.2 | 40 | 704 |
| 10.7 | 40 | 729 |
| 12.2 | 40 | 735 |
| M12.2[c] | 40 | 727 |
| −9.2 | — | 559 ± 8 |

**8 in. Outfall: Line M Center of Outfall (11/2/77)**

| Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| −9.2[c] | — | 559 ± 8 |
| −3.10 | 35 | 606 |
| −1.5[d] | 40 | 637 |
| 0.0 | 35 | 638 |
| 1.5 | 35 | 704 |
| 3.1 | 35 | 784 |
| 4.6 | 40 | 641 |
| 6.1 | 40 | 695 |
| 7.6 | 40 | 645 |
| 9.2 | 40 | 702 |
| 10.7 | 40 | 669 |
| 12.2[c] | 40 | 676 |
| −9.2[c] | — | 539 |

**8 in. Outfall: Line O North of Line M (11/2/77)**

| Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| −9.2[c] | — | 394 ± 35 |
| −1.5[d] | 40 | 493 |
| 0.0 | 35 | 657 |
| 1.5 | 35 | 576 |
| 3.1 | 40 | 649 |
| 4.6 | 35 | 659 |
| 6.1 | 40 | 696 |
| 7.7 | 40 | 721 |
| 9.2 | 40 | 826 |
| 10.7 | 40 | 720 |
| 12.2 | 40 | 683 |
| 13.8[e] | 40 | 679 |
| 15.3[f,d] | 40 | 650 |
| M12.2[c] | 20 | 570 |
| −9.2 | 30 | 415 |

**8 in. Outfall: Line P West of Line O (11/3/77)**

| Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| — | — | — |
| −9.2[c] | 0 | 415 |
| −1.5 | 35 | 586 |
| 0.0 | 30 | 665 |
| 1.5 | 40 | 578 |
| 3.1 | 40 | 580 |
| 4.6 | 35 | 578 |
| −9.2[c] | — | — |
| — | — | — |
| — | — | — |
| — | — | — |
| — | — | — |
| — | — | — |
| — | — | — |

[a]The Ludlum 12-S responds to photons over 20 keV. See Appendix for details.

[b]The phoswich responds to photons from 5 to 25 keV. See Appendix for details.

[c]Background count. A preliminary background count as well as a concluding background count were made for most descents.

[d]Some measurements were made back from the rim of the mesa on the mesa top. Others were made down the talus slope below the base of the cliff. In these cases the distance conforms to the orientation of the ground surface rather than being projected onto the vertical plane above or below the cliff.

[e]These readings are at the base of the cliff.

[f]These readings were taken on the talus slope.

TABLE D-XXI (cont)

INSTRUMENT READINGS FROM CLIFF SURVEYS

| Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) | Depth Below Mesa Rim (m) | Ludlum 12S[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|---|---|---|
| 8 in. Outfall: Line Q West of Line P (11/3/77) | | | 8 in. Outfall: Line R West of Line Q (11/3/77) | | |
| −9.2[c] | --- | --- | −9.2[c] | --- | 557 ± 29 |
| 0.0 | 30 | 652 | 0.0 | 35 | 639 |
| 1.5 | 35 | 652 | 1.5 | 35 | 725 |
| 3.1 | 35 | 633 | 3.1 | 35 | 707 |
| 4.6 | 35 | 629 | 4.6 | 35 | 802 |
| 6.1 | 35 | 615 | 6.1 | 35 | 746 |
| 7.7 | 40 | 628 | 8.2 | 35 | 741 |
| 9.2 | 40 | 669 | 7.7 | 40 | 761 |
| 10.7 | 35 | 709 | 9.2 | 40 | 757 |
| 12.2 | 40 | 715 | 10.7 | 40 | 836 |
| 13.8 | 40 | 779 | M12.2 | --- | 750 |
| −9.2[c] | --- | --- | −9.2 | --- | 640 |
| 8 in. Outfall: Line S South of Line N (11/3/77) | | | 8 in. Outfall: Line T South of Line S (11/3/77) | | |
| −9.2[c] | --- | 640 | −9.2[c] | --- | 541 |
| −1.5 | 30 | 613 | −1.5 | 30 | 622 |
| 0.0 | 30 | 643 | 0.0 | 30 | 560 |
| 1.5 | 35 | 661 | 1.5 | 30 | 626 |
| 3.1 | 40 | 726 | 3.1 | 40 | 653 |
| 9.2 | 40 | 747 | 4.6 | 40 | 595 |
| --- | --- | --- | 6.1 | 40 | 640 |
| --- | --- | --- | 7.7 | 40 | 616 |
| --- | --- | --- | 9.2 | 40 | 655 |
| --- | --- | --- | 10.7 | 40 | 578 |
| --- | --- | --- | 12.2 | 40 | 607 |
| --- | --- | --- | M12.2[c] | --- | 591 |

TABLE D-XXI (cont)

INSTRUMENT READINGS FROM CLIFF SURVEYS

**6 in. Outfall: Line A (11/4/77)**

| | Depth Below Mesa Rim (m) | Ludlum 125[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|---|
| Center | −9.2[c] | 30 | 45 ± 3 |
| W wall | 0.0 | 35 | 508 |
| E wall | 0.9 | 30 | 467 |
| W wall | 0.9 | 35 | 509 |
| Center | 1.8 | 35 | 525 |
| E wall | 1.8 | 40 | 543 |
| W wall | 1.8 | 35 | 567 |
| Center | 2.7 | 35 | 542 |
| E wall | 2.7 | 35 | 531 |
| W wall | 2.7 | 35 | 518 |
| | 3.7 | 35 | 610 |
| | | | — |

**6 in. Outfall: Line A (11/4/77)**

| | Depth Below Mesa Rim (m) | Ludlum 125[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|---|
| Center | 3.7 | 40 | 578 |
| E wall | 3.7 | 35 | 845 |
| W wall | 4.6 | 35 | 814 |
| Center | 4.6 | 40 | 652 |
| E wall | 4.6 | 35 | 756 |
| W wall | 5.5 | 40 | 791 |
| Center | 5.5 | 40 | 675 |
| E wall | 5.5 | 40 | 661 |
| W wall | 6.4 | 40 | 775 |
| Center | 6.4 | 40 | 721 |
| E wall | 6.4 | 35 | 769 |
| — | −9.2[c] | — | 553 |

**Line C: Untreated Outfall (11/4/77)**

| Depth Below Mesa Rim (m) | Ludlum 125[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| −9.2[c] | — | 602 |
| −1.5[d] | 30 | 451 |
| −0.8[d] | 35 | 2956 |
| −0.5[d] | 35 | 701 |
| 0.0 | 35 | 712 |
| 1.5 | 40 | 525 |
| 3.0 | 35 | 476 |
| 4.6 | 40 | 503 |
| 6.1 | 40 | 411 |
| 7.6[e] | 35 | 402 |
| 7.9[f] | 40 | 427 |
| −9.2[c] | — | 543 |

**Line B: Truck Wash Drain (11/4/77)**

| Depth Below Mesa Rim (m) | Ludlum 125[a] (μR/h) | Phoswich[b] (counts/100 s) |
|---|---|---|
| −10.0[c] | — | 419 |
| 0.0 | 35 | 429 |
| 1.5 | 35 | 336 |
| 3.1 | 40 | 353 |
| 4.6 | 40 | 423 |
| 6.1 | 40 | 477 |
| 8.3[e] | 60 | 637 |
| −10.0[c] | — | 457 |
| — | — | — |
| — | — | — |
| — | — | — |
| — | — | — |

## TABLE D-XXII

### SCOOP SAMPLES 0-5 cm

| Location | Gross $\beta$ | Gross $\alpha$ | $^{239,240}$Pu | $^{241}$Pu |
|---|---|---|---|---|
| **Middle Pueblo Canyon** | | | | |
| G-17 | 1 | 20 | | |
| **Lower Pueblo Canyon** | | | | |
| G-19 | 2 | 30 | | |
| G-1 | 2 | 20 | | |
| G-28 | 0 | 30 | | |
| G-18 | 2 | 40 | 4.49 | 0.0 |
| G-23 | 0 | 10 | | |
| G-25 | 3 | 60 | 6.82 | 0.085 |
| G-26 | 1 | 30 | | |
| G-20 | 2 | 20 | | |
| G-4 | 4 | 20 | | |
| G-9 | 2 | 10 | | |
| G-14 | 1 | 30 | | |
| G-13 | 2 | 10 | | |
| G-11 | 4 | 30 | | |
| G-30 | 0 | 10 | | |
| G-12 | 2 | 20 | | |
| G-2 | 1 | 20 | | |
| G-3 | 4 | 20 | | |
| G-10 | 3 | 20 | | |
| **Lower Los Alamos Canyon** | | | | |
| G-8 | 4 | 20 | | |
| G-6 | 3 | 30 | | |
| G-27 | 2 | 30 | | |
| G-22 | 1 | 20 | | |
| G-16 | 1 | 30 | | |
| G-15 | 1 | -20 | | |
| G-29 | 0 | 10 | | |
| G-24 | 1 | 0 | | |

TABLE D-XXIII

TRANSECT SAMPLE IDENTIFICATION

| Transect | Active Channel Sample Numbers | Active Channel Width (m) | Inactive Channel Sample Numbers | Inactive Channel Width (m) | Banks Sample Numbers | Banks Width (m) |
|---|---|---|---|---|---|---|
| **Middle Pueblo Canyon** | | | | | | |
| 15900 | −1 | 1.5 | | 0 | −0, −2 | 14 |
| 15500 | | 1.5 | | 0 | −0 | 10.5 |
| 14950 | | 2 | | 0 | | 15 |
| 14150 | −1 | 5 | | 0 | −0, −2 | 25 |
| OAPII | all | | | | | |
| 13650 | | 3.5* | | 0 | | 2 |
| **Lower Pueblo Canyon** | | | | | | |
| 13150 | −1 | 1 | | 0 | −0, −2 | 7 |
| APII | 10-1, 5-1 | --- | | --- | 10-0, 10-2, 5-0, 5-2 | --- |
| 12850 | | 2 | −3 | 8 | −3 | 9 |
| 12650 | −1 | 3 | −0, −2 | 15 | −3 | 8 |
| 11850 | −3 | 4 | −0, −1, −2, −4 | 10 | | 2 |
| 11550 | | 3 | | 14 | | 6 |
| 10650 | −1 | 6 | −0 | 11 | −2 | 4 |
| 10050 | | 6 | | 20 | | 2 |
| 9650 | | 4 | −3 | 16 | | 0.3 |
| 8150 | −1, −2, −3, −5, −7 | 26 | −4, −6, −8 | 104 | −0 | 9 |
| 7950 | −1, −2 | 8 | −3 | 10 | −0 | 10 |
| 7650 | | 5 | | 20 | | 8 |
| **Lower Los Alamos Canyon** | | | | | | |
| 7250 | 1 | 1.3 | | 0 | −0, −2 | 3 |
| 5900 | −1 | 1.3 | | 0 | −0, −2 | 2 |
| 5800 | −1 | 2 | | 0 | −0, −2 | 2 |
| 5700 | −1 | 3 | | 0 | −0, −2 | 2 |
| 5100 | | 4 | | 13 | | 4 |
| 5000 | | 6 | | 15 | | 2 |
| 4300 | | 4 | | 2 | | 0.6 |
| 3700 | 1, −2 | 9 | −0, −3 | 37 | | 0.6 |
| 3200 | −1, −2, −3, −4 | 25 | −5 | 35 | −0 | 0.6 |
| 2500 | | --- | | --- | −5 | --- |
| 800 | −1, −2 | 32 | −0, −3, −4 | 47 | −0 | 2 |
| 400 | | 36 | | 32 | | 1 |
| 0 | | 39 | | 0 | | 0.6 |

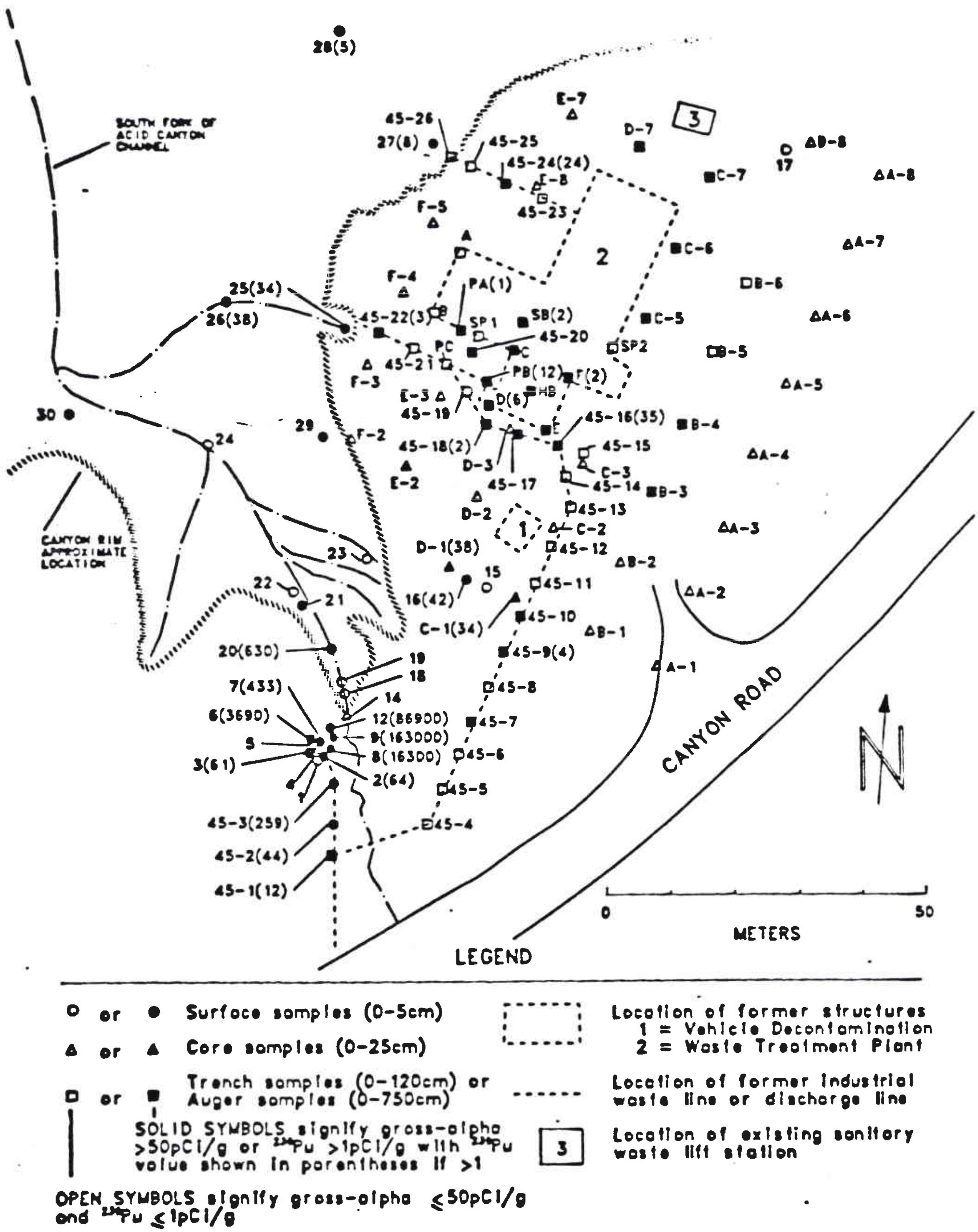


*Fig. E-1.*

*Sampling locations and summary results, treatment plant site and part of Acid Canyon.*

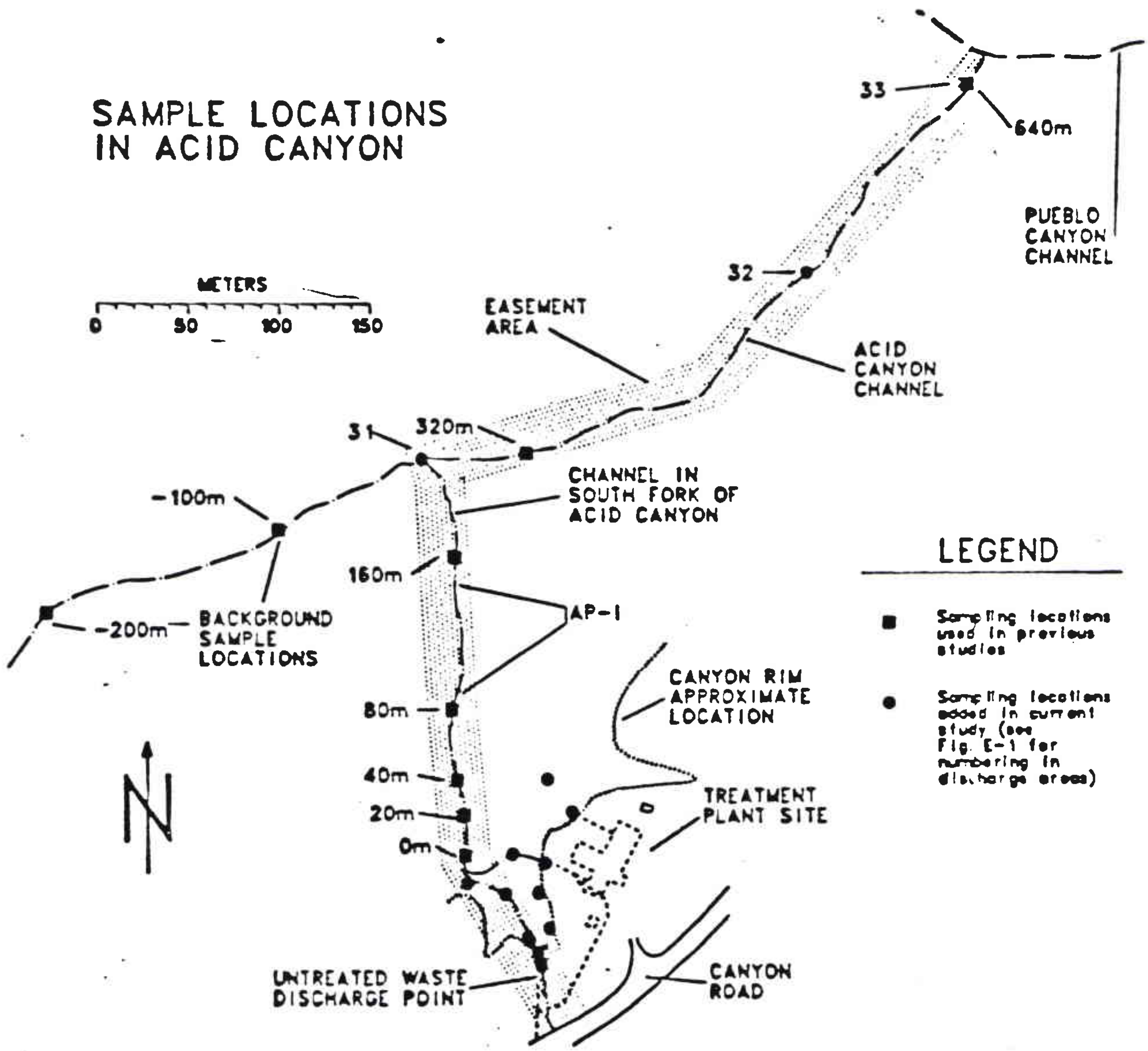


*Fig. E-2.*
*Sampling locations in Acid Canyon.*

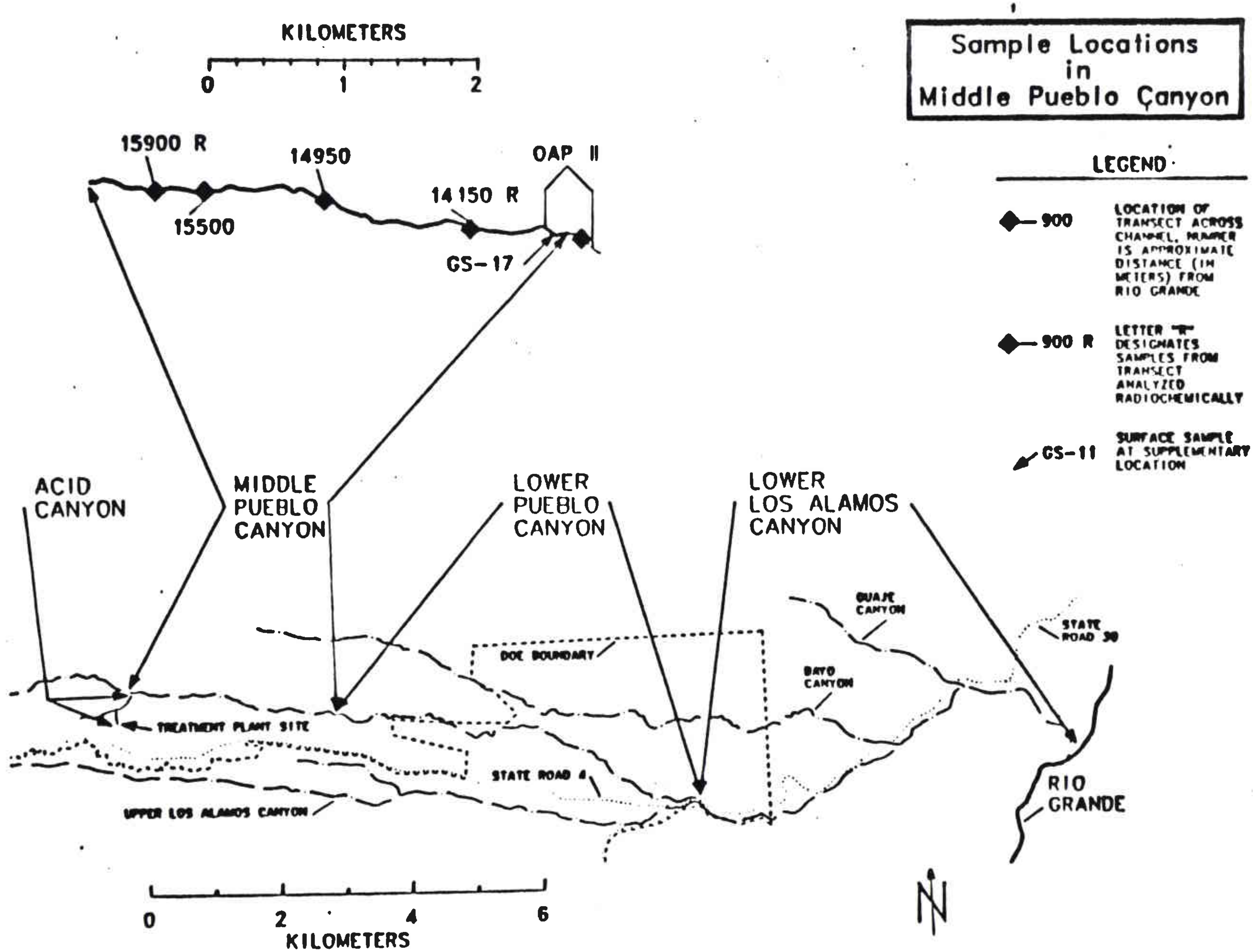


Fig. E-3.
*Sampling locations in Middle Pueblo Canyon.*

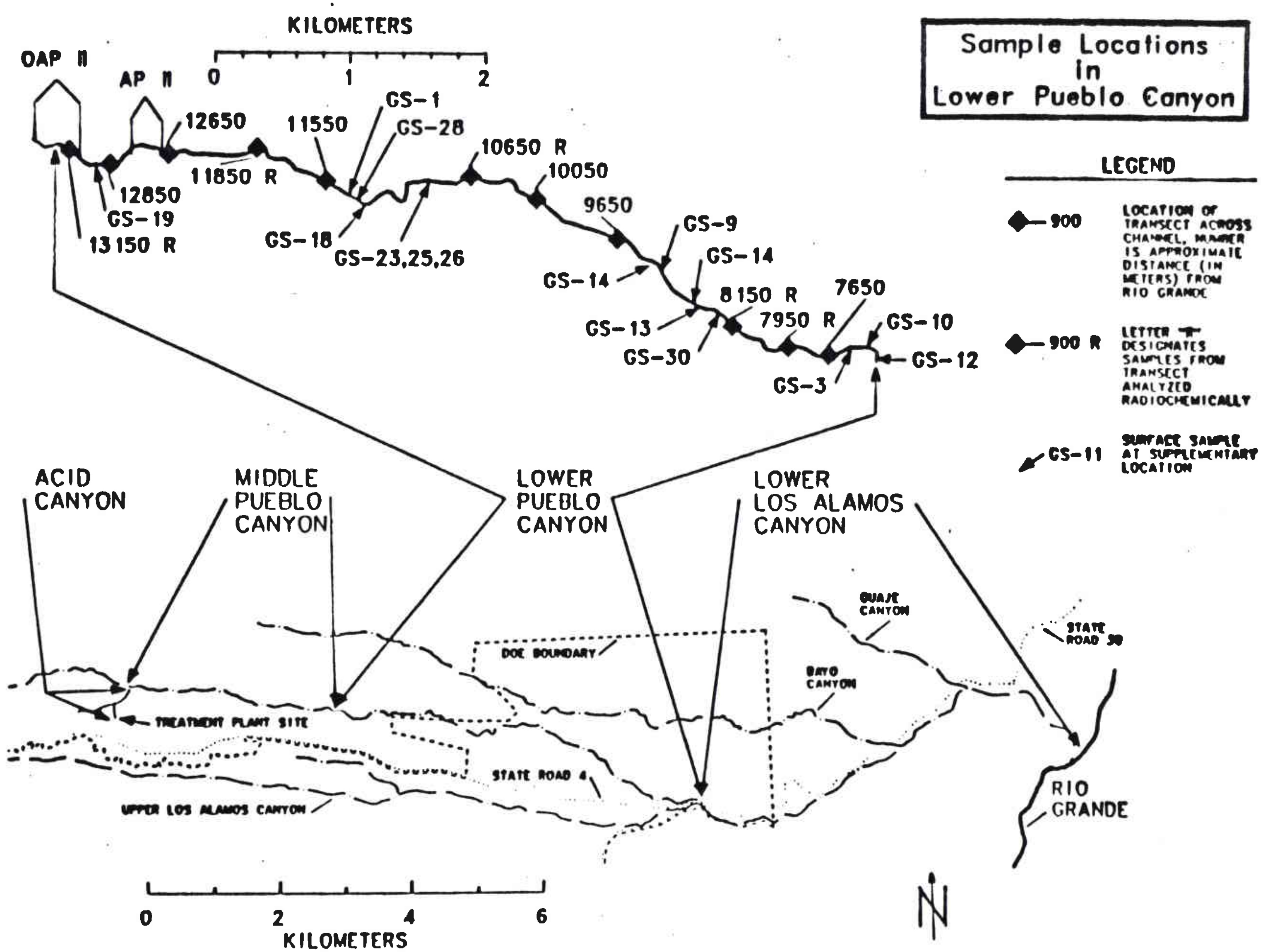


*Fig. E-4.*
*Sampling locations in Lower Pueblo Canyon.*

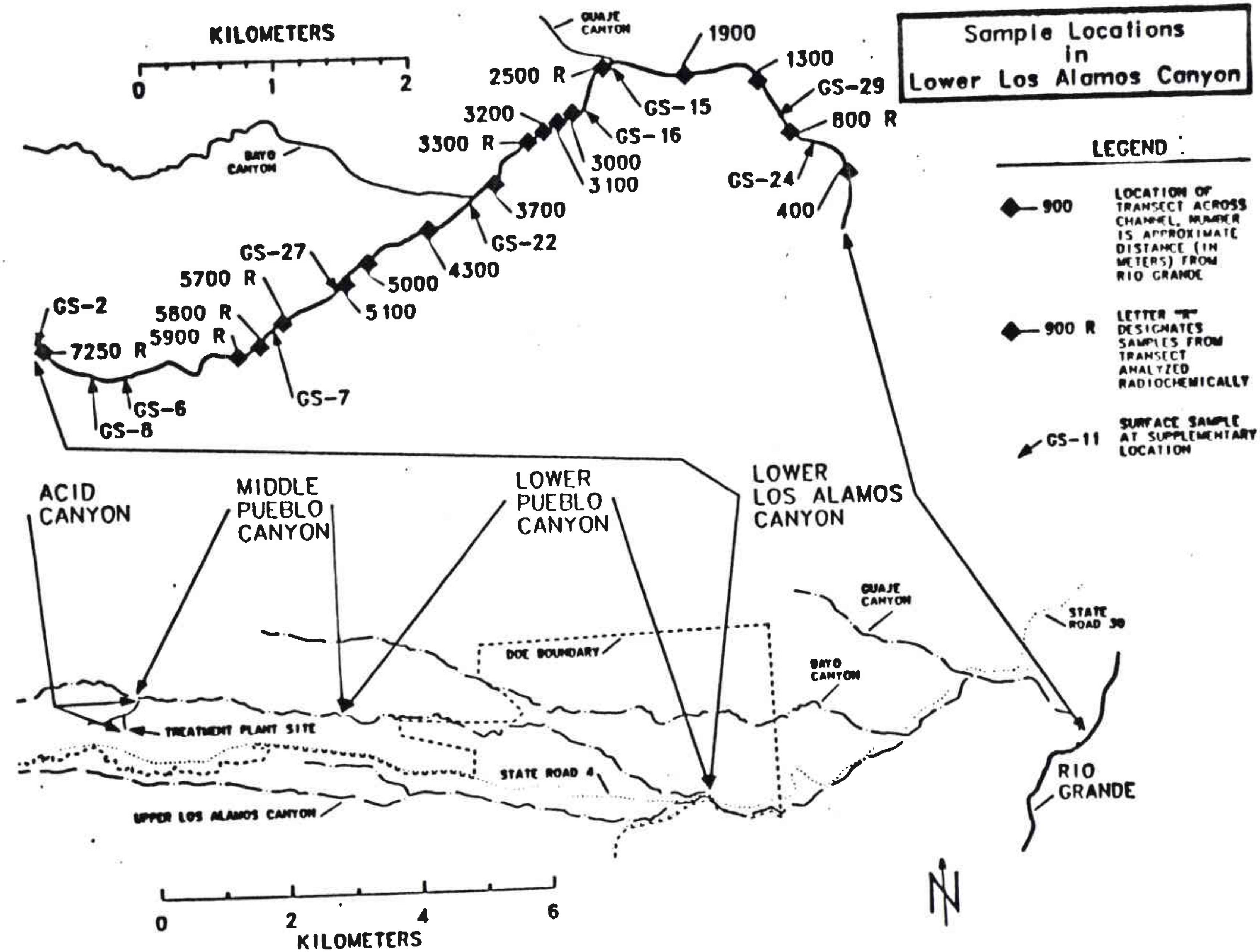


Fig. E-5.
Sampling locations in Lower Los Alamos Canyon.

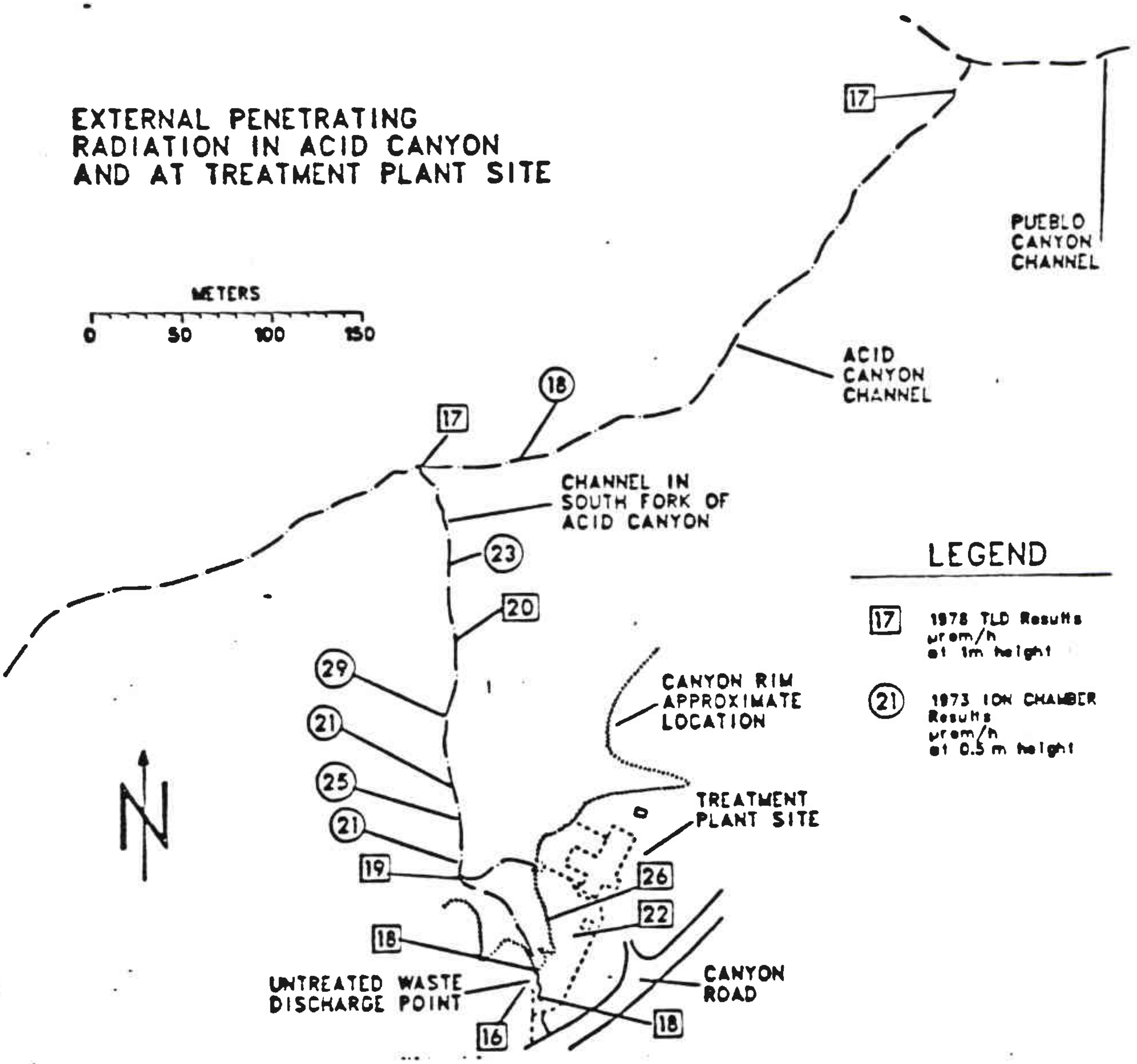


*Fig. E-6.*
*External penetrating radiation measurements, Treatment Plant Site and Acid Canyon.*

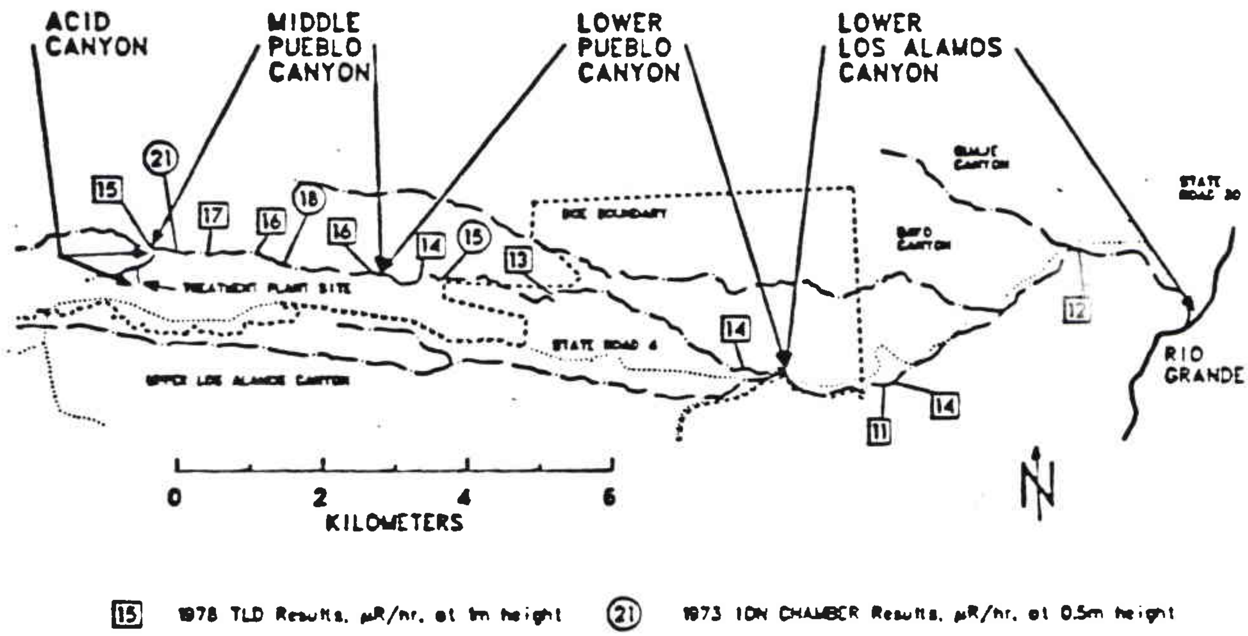


*Fig. E-7.*
*External penetrating radiation measurements, Pueblo and Los Alamos Canyons.*

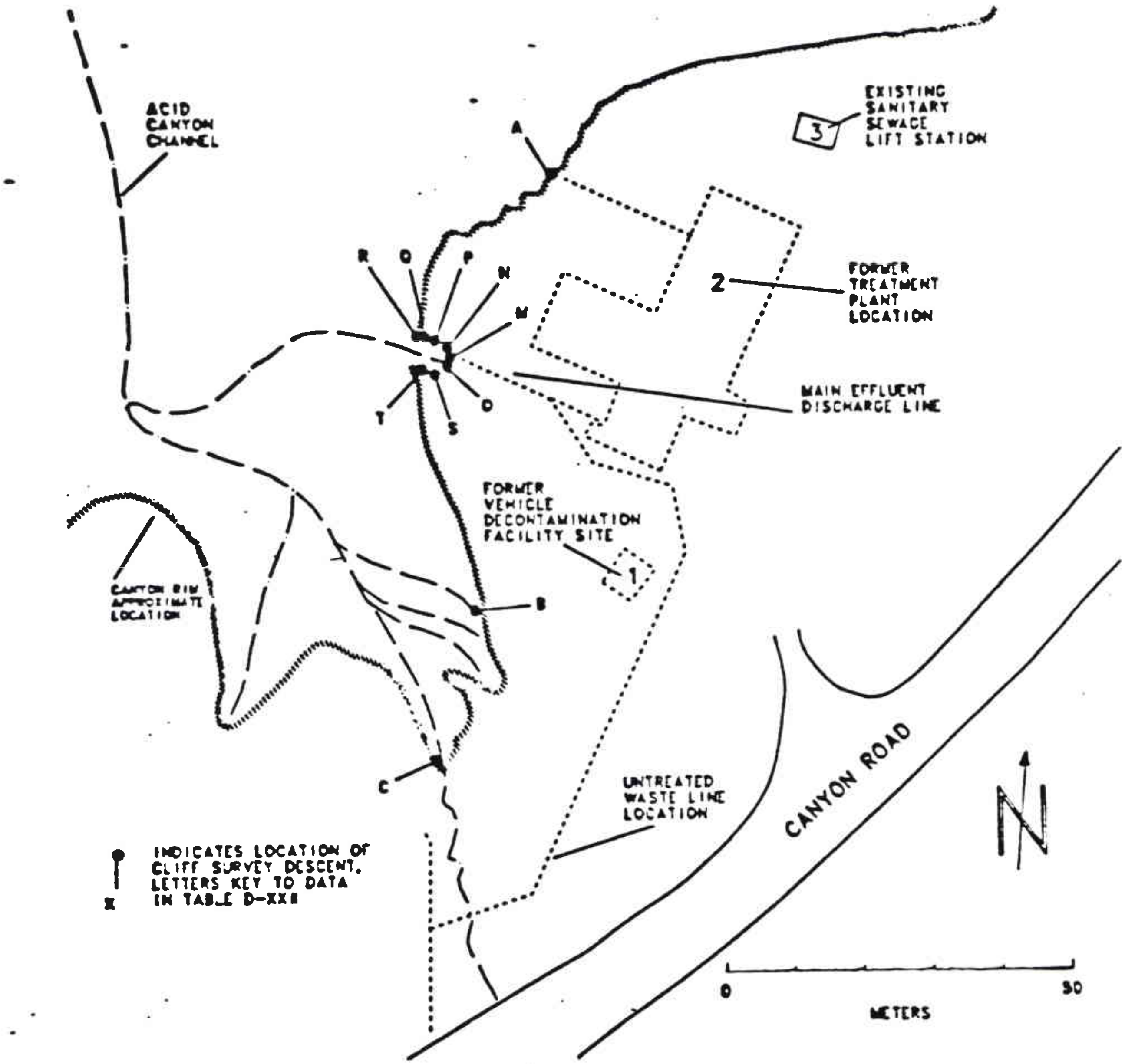


*Fig. E-8.*
*Locations of cliff survey descents in vicinity of Treatment Plant Site and Acid Canyon.*

# ACID/PUEBLO CANYON GLOSSARY

## ACID/PUEBLO CANYON GLOSSARY

| Abbreviations/Terms | Definitions |
|---|---|
| AEC | Atomic Energy Commission |
| alpha particle ($\alpha$) | A positively charged particle emitted from certain radioactive material. It consists of two protons and two neutrons, hence is identical with the nucleus of the helium atom. It is the least penetrating of the common radiation ($\alpha$, $\beta$, $\gamma$), hence is not dangerous unless alpha-emitting substances have entered the body. |
| Americium (Am) | A radioactive element, not found in nature, formed in high-energy nuclear reactions. Americium-241 decays by alpha radiation with a half-life of 433 years. |
| aquifer | A water-bearing formation below the surface of the earth; the source of wells. |
| background radiation | Naturally occurring low-level radiation to which all life is exposed. Background radiation levels vary from place to place on the earth. |
| beta particle ($\beta$) | A particle emitted from some atoms undergoing radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Beta radiation can cause skin burns and beta emitters are harmful if they enter the body. |
| Cesium-137 (Cs-137) | A radioactive isotope of cesium, which is an element chemically similar to sodium and potassium. Cesium-137 has a half-life of 30.1 years and decays by beta emission to $Ba^{m}$-137; this daughter decays almost immediately to Ba-137 by emitting a 662 keV gamma ray. Cesium-137 is formed as a fission product in nuclear fissioning, and is important because of the long half-life and relatively high rate of production. |

| | |
|---|---|
| Ci | Curie (the unit of radioactivity of any nuclide, defined as precisely equal to 3.7 x $10^{10}$ disintegrations/second) |
| daughter product | The nuclide remaining after a radioactive atom (parent) has undergone radioactive decay. A daughter atom also may be radioactive, producing further daughter products. |
| EGR | External gamma radiation (gamma radiation emitted from a source(s) external to the body, as opposed to internal gamma radiation emitted from ingested or inhaled sources). |
| EPA | Environmental Protection Agency. |
| ERDA | Energy Research and Development Administration |
| erg | The basic unit of work or energy in the centimeter-gram-second system (One erg is equal to 7.4 x $10^{8}$ ft-lb.) |
| exhalation | Emission of radon from earth (usually thought of as coming from a uranium tailings pile, but actually from any location). |
| exposure | Magnitude of radiation to which a person is subjected. It is defined and measured by electrical charge produced per unit mass of air. |
| FB&DU | Ford, Bacon & Davis Utah Inc. |
| gamma background | Natural gamma ray activity everywhere present, originating from two sources: (1) cosmic radiation, bombarding the earth's atmosphere continually, and (2) terrestrial radiation. Whole body absorbed dose equivalent in the U.S. due to natural gamma background ranges from about 60 to about 125 mrem/yr. |
| gamma ray ($\gamma$) | High energy electromagnetic radiation emitted from the nucleus of a radioactive atom, with specific energies for the atoms of different elements and having high penetrating power. |
| ground water | Subsurface water in the zone of full saturation which supplies wells and springs. |

| | |
|---|---|
| health effect | Adverse physiological response to pollutants from tailings (in this report, one health effect is defined as one case of lung cancer produced from inhalation of radioactive materials). |
| Interim Primary Drinking Water Regulations | Title No. 40 of the Code of Federal Regulations, EPA Chapter 1, Part 141, dated July 9, 1976. |
| isotope | A nuclide having the same number of protons (and hence the same atomic number) as another nuclide, but with differing numbers of neutrons. All isotopes of one atomic number are the same element. |
| LANL | Los Alamos National Laboratory |
| $\mu$ (micro) | A prefix in the metric system, signifying $10^{-6}$, or one-millionth. |
| $\mu$R/hr | Microroentgen per hour |
| mR/hr | Milliroentgen per hour |
| MPC | Maximum permissible concentration (the highest concentration in air or water of a particular radionuclide permissible for occupational or general exposure without taking steps to reduce exposure). |
| noble gas | One of the gases, such as helium, neon, radon, etc., with completely filled electron shells which is therefore chemically inert. |
| NRC | Nuclear Regulatory Commission |
| nuclide | A general term applicable to all atomic forms of the elements; nuclides comprise all the isotopic forms of all the elements. Nuclides are distinguished by their atomic number, atomic mass, and energy state. |
| pico | A prefix in the metric system, signifying 10-12, or one millionth of one millionth. |
| pCi/l | Picocurie per liter |

| | |
|---|---|
| Plutonium (Pu) | A radioactive element, found in nature only in trace amounts, but produced in quantity in nuclear reactors. Plutonium, because of radioactivity and high chemical toxicity, is considered a dangerous material. The most common isotope of plutonium is Pu-239, which is fissionable and represents a great potential source of energy for the United States. The half-life of Pu-239 is about 24,000 years; it decays by alpha emission. |
| Potassium-40 (K-40) | A naturally occurring radioactive isotope of potassium decaying by beta radiation with an accompanying gamma ray. The half-life of K-40 is 1.29 x $10^9$ yr. As an isotope of potassium, K-40 tends to concentrate in the soft tissues of the body. |
| R | Roentgen (a unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying 1 electrostatic unit of electrical charge, either positive or negative, in 1 cubic centimeter of dry air under standard conditions numerically equal to 2.58 x $10^{-4}$ coulombs/kg) |
| rad | The basic unit of absorbed dose of ionizing radiation. A dose of 1 rad means the absorption of 100 ergs of radiation energy per gram of absorbing material. |
| radioactivity | The spontaneous decay or disintegration of an unstable atomic nucleus, usually accompanied by the emission of ionizing radiation. |
| radioactive decay chain | A succession of nuclides, each of which transforms by radioactive disintegration into the next, until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product. |
| radium | A radioactive element chemically similar to barium, formed as a daughter product of uranium (U-238). The most common isotope of radium, Ra-226, has a |

| | |
|---|---|
| | half-life of 1,600 yr. Radium is present in all uranium-bearing ores. Trace quantities of both uranium and radium are found in all areas, contributing to the gamma background. |
| radon | A radioactive, chemically inert gas, having a half-life of 3.8 days (Rn-222); formed as a daughter product of radium (Ra-226) |
| radon background | Low levels of radon gas found in an area, due to the presence of uranium or radium in the soil. |
| radon concentration | The amount of radon per unit volume. |
| radon daughter | One of several short-lived radioactive daughter products of radon (several of the daughters emit alpha particles). |
| RDC | Radon daughter concentration (the concentration in air of short-lived radon daughters, expressed usually in pCi/l; also measured in terms of working level (WL)). |
| radon flux | The quantity of radon emitted in a unit time per unit area (typical units are in pCi/m2-s). |
| recharge | The processes by which water is absorbed and added to the zone of saturation of an aquifer, either directly into the formation or indirectly by way of another formation. |
| rem | (Acronym for roentgen equivalent man) The unit of dose for any ionizing radiation which produces the same biological effect as a unit of absorbed dose of ordinary X-rays, numerically equal to the absorbed dose in rads multiplied by the appropriate quality factor for the type of radiation. The rem is the basic recorded unit of accumulated dose to personnel. |
| scintillometer | A radiation detection instrument used for monitoring small changes in background and for low-level radiation, normally utilizing a NaI crystal as a scintillator. |

| | |
|---|---|
| Strontium-90 (Sr-90) | A radioactive isotope of strontium, which is an element chemically similar to calcium. Strontium-90 is formed as a fission product in nuclear reactors and fission explosions. It has a half-life of 28.1 years and decays by beta emission to yttrium-90 (Y-90), which also decays (half-life of 64 hours) by beta emission. Because Sr-90 tends to deposit in bone tissue, it is a significant hazard to exposed populations. |
| Thorium-232 (Th-232) | A radioactive element, found in nature. Thorium-232 (half-life of $1.4 \times 10^{10}$ years) is the precursor of a chain of radioactive elements, each decaying with its characteristic half-life to the next, until the chain ends at stable Pb-208. Thorium-230 is a member of the uranium decay chain and is the immediate precursor to Radium-226. |
| WL | Working level. A unit of radon daughter exposure, equal to any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of $1.3 \times 10^5$ MeV of potential alpha energy. This level is equivalent to the energy produced in the decay of the daughter products RaA, RaB, RaC, and RaC' that are present under equilibrium conditions in a liter of air containing 100 pCi of Rn-226. It does not include decay of RaD (22 year half-life) and subsequent daughter products. |
| Uranium (U) | A radioactive element found in nature. Natural uranium metal consists of 99.27% U-238, 0.72% U-235, and trace amounts of U-234. Both U-238 and U-235 are precursors for radioactive decay chains, consisting of a series of radioactive elements ending for U-238 with Pb-206, and for U-235 with Pb-207. The U-238 decay chain includes Th-230, Ra-226, and Rn-222 within the chain and is thus a significant factor in radiation protection. |
| WLM | Working level month. One WLM is equal to the exposure received from 170 WL hours. |